United States Department of Agriculture

Conservation Strategy for the California Spotted Owl in the Sierra Nevada

Version 1.0

Forest Service Pacific Southwest Region R5-TP-043 April 2019

Photo from the University of Wisconsin-Madison.

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Preface

The California spotted owl (*Strix occidentalis occidentalis*) Conservation Strategy is a strategic framework for active conservation of the California spotted owl on National Forest System lands in the Sierra Nevada. This Strategy provides scientific information and management recommendations; it is not a legally enforceable document that commits to any agency action or inaction. The intent of this Strategy is to apply adaptive management as new information becomes available and conservation outcomes are achieved. Development, review, and editing of this document was conducted by USDA Forest Service, Pacific Southwest Region. Public review was conducted in spring 2018. External peer review was conducted in fall 2018, prior to finalizing the strategy.

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Introduction

For more than a quarter of a century, the Forest Service has been engaging in proactive California spotted owl conservation focusing on retaining suitable habitat and minimizing disturbance to breeding owls. Several factors have emerged suggesting a new strategy is needed to maintain owl persistence and to develop resilient owl habitat. New science indicates threats to spotted owls are shifting and evolving, environmental conditions are changing, and owl populations are declining in some areas of the species' range.

The "Conservation Strategy for the California Spotted Owl in the Sierra Nevada" (Strategy) has been developed to achieve three main goals for the California spotted owl across the species' range: (1) promote and maintain well-distributed owl habitat by developing key habitat elements and connectivity; (2) promote California spotted owl persistence by enhancing habitat resilience to multiple disturbances, considering climate change; and (3) maintain a well-distributed and stable California spotted owl population by minimizing impacts from non-habitat threats. The Strategy's conservation approaches and measures are designed to achieve desired conservation outcomes for the California spotted owl.

The Strategy is primarily based on the following sources:

- The California Spotted Owl: Current State of Knowledge [PSW-GTR-254 (Gutiérrez, et al. (technical editors) 2017)]
- United States Fish and Wildlife Conservation Objectives Report (U.S. Fish and Wildlife Service 2017)
- Natural Range of Variation for Yellow Pine Mixed-Conifer Forests in the Sierra Nevada, Southern Cascades, and Modoc and Inyo National Forests [PSW-GTR-256 (Safford and Stevens 2017)]
- emerging new science
- local expertise and public input

The Strategy is meant to be a living document that can be modified as new information becomes available.

Geographic Scope

The Strategy focuses on the 10 Sierra Nevada national forests within the Pacific Southwest Region, which comprise the majority of owl abundance and distribution (figure 1). Most of the information on which this Strategy is based was gathered west of the Sierra Crest, particularly in the mid-elevation, mixed-conifer forests on the west slope of the Sierra Nevada where the majority of the owls occur (Verner et al. 1992). However, many of the recommendations and measures in this Strategy can be applied range wide for the conservation of the California spotted owl. A 2004 strategy exists for California spotted owl populations on national forests in southern California (USDA Forest Service 2004a) and should also be updated to reflect new information and conditions in that part of the species' range.

Section 1. Guiding Principles

Forests that support California spotted owl (CSO) populations are dynamic ecosystems operating at multiple scales with diverse vegetation types, structures, functions, and processes that vary over space and time. Current forest conditions are generally departed from historic conditions and today's forests are expected to be less resilient to future conditions like increasing temperatures, changes in precipitation and fire regimes, and increased drought (Stephens et al. 2016a). CSO populations have been declining in portions of their range and emerging threats (mega fires, climate change, barred owl range expansion, toxicant exposure) are causing concern for maintaining CSO persistence on the landscape.

This Strategy focuses on the immediate need for maintaining high-quality habitat, especially around occupied nest sites, while developing resilient habitat across the landscape. Maintaining well-distributed territories across the CSO range will increase population resilience to the effects of climate change and other environmental stressors. Historic abundance and density of the CSO remain unknown; however, historic ecological conditions in which the CSO evolved and persisted, as in the natural range of variation (NRV) of the Sierra Nevada, are better understood (Safford and Stevens 2017, page 244). Managing the landscape toward NRV is a central and guiding principle of this Strategy and can help develop resilient habitat conditions that provide CSO conservation in the long term. Development of resilient landscapes will not happen overnight. The conservation measures aimed at maintaining the CSO and their suitable habitat where they exist today provide some immediate stability for individual owls while we work to align the landscape with NRV. This Strategy recognizes this may entail some short-term, localized risk to resilience as more sustainable and dynamic habitat is developed through active management. Aligning the landscape with NRV is the first step towards an eventual resilient future range of variation.

Section 2. Vision

The Forest Service's vision for the future of the California spotted owl is:

Thriving, well-distributed owl populations with diverse habitat that is resilient to disturbances at multiple scales over the long term (decades to centuries).

Section 3. California Spotted Owl Ecology

Geographic Range and Distribution

The CSO occurs in the Sierra Nevada mountain range, the mountains of central coastal California, and the peninsular and transverse ranges of southern California. CSO distribution is geographically distinct between the Sierra Nevada and southern California populations (Verner et al. 1992). Approximately 75 percent of the CSO's range (5 million acres [2 million hectares]), is on national forests (Gutiérrez et al. 2017).

The CSO is continuously distributed on the western slope of the Sierra, with fewer detections on the drier, east side of the range (figure 1) (Verner et al. 1992). The CSO inhabits elevations ranging from 1,000 to 7,740 feet in the Sierra (86 percent of owls occur between 3,000 and 7,000 feet) and up to 8,500 feet in southern California (Stephenson 1991, Verner et al. 1992).

Population Trends

Information on CSO demographic rates comes from long-term demography studies, three of which occur primarily on National Forest System lands in the Sierra Nevada (Lassen, Eldorado, and Sierra) and one which occurs on the Sequoia and Kings Canyon National Parks (figure 2). Studies began in 1986 on the Eldorado and in 1990 in the other areas. Another demography study occurred in southern California on the San Bernardino National Forest from 1988 to 2000 (figure 2). The study areas on national forests (Sierra Nevada Mountains and San Bernardino Mountains) were derived from a subset of areas of concern for the CSO identified in the CASPO Technical Report (Verner et al.1992). While these demography studies have been the sole source of empirical data about population trends, they may not be entirely representative of forest, ecological province, or rangewide trends for the CSO (see Verner et al. 1992, chapter 1, for detailed information on CSO areas of concern).

From the 1990s to 2013 in the Sierra Nevada, CSO populations declined within the demography study areas on national forests: Sierra (31 percent), Lassen (44 percent), and Eldorado (50 percent) (Conner et al. 2016, Tempel et al. 2014b). Reproduction appears to be relatively constant in all study areas in the Sierra Nevada except the Eldorado, where measured parameters continue to be highly variable between years (Blakesley et al. 2010). The Sequoia-Kings Canyon National Park (SEKI) population appears to be stable or increasing over the same period. Differences in population trends between the national forests and the national parks could be related to forest management strategies (Blakesley et al. 2005, Seamans and Gutiérrez 2007, Tempel et al. 2014a). For example, the disparity may be related to SEKIs recent extensive and growing use of fire for ecological restoration, while general fire suppression has continued on National Forest System lands (Kilgore and Taylor 1979, van Wagtendonk 2007). The most recent scientific analysis indicates current population declines in the study areas on National Forest System lands are likely not the result of current forest management strategies but are instead likely a lag effect from historic large tree removal and a century of fire suppression (Jones et al. 2017). Continued fire suppression and other activities that maintain or increase forest homogeneity are likely contributing to these declines, due to effects on CSO prey species (Hobart et al. in review).

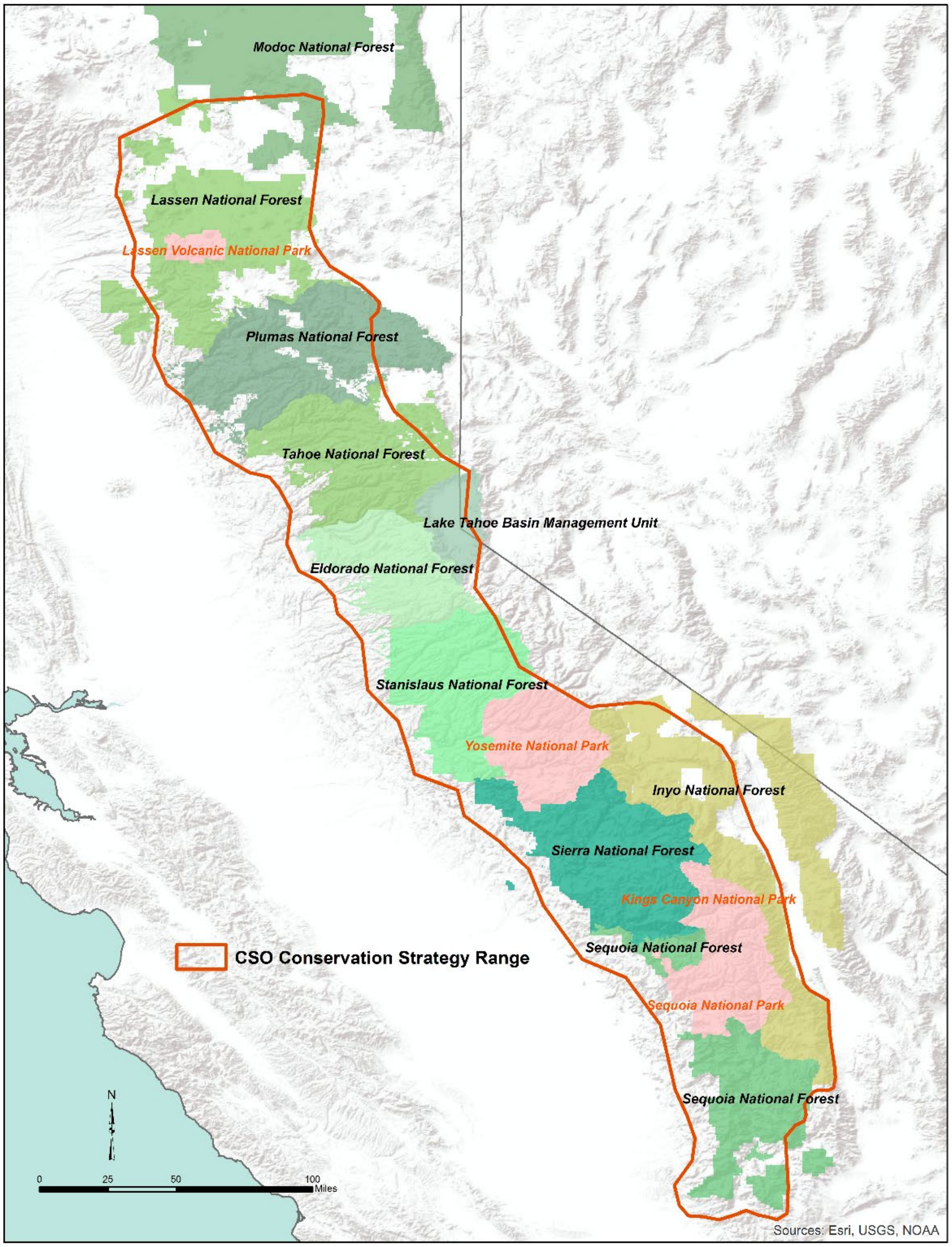

Figure 1. California spotted owl conservation strategy area for the Sierra Nevada

CSO habitat also occurs on land that is privately owned by companies like Sierra Pacific Industries (SPI), a large forest products company. SPI has initiated systematic surveys on five study areas throughout the Sierras. On SPI lands, 45 CSO territories were occupied prior to 1996, and all 45 were occupied at least once during the recent study period from 2012 to 2016 (Roberts et al. 2017).

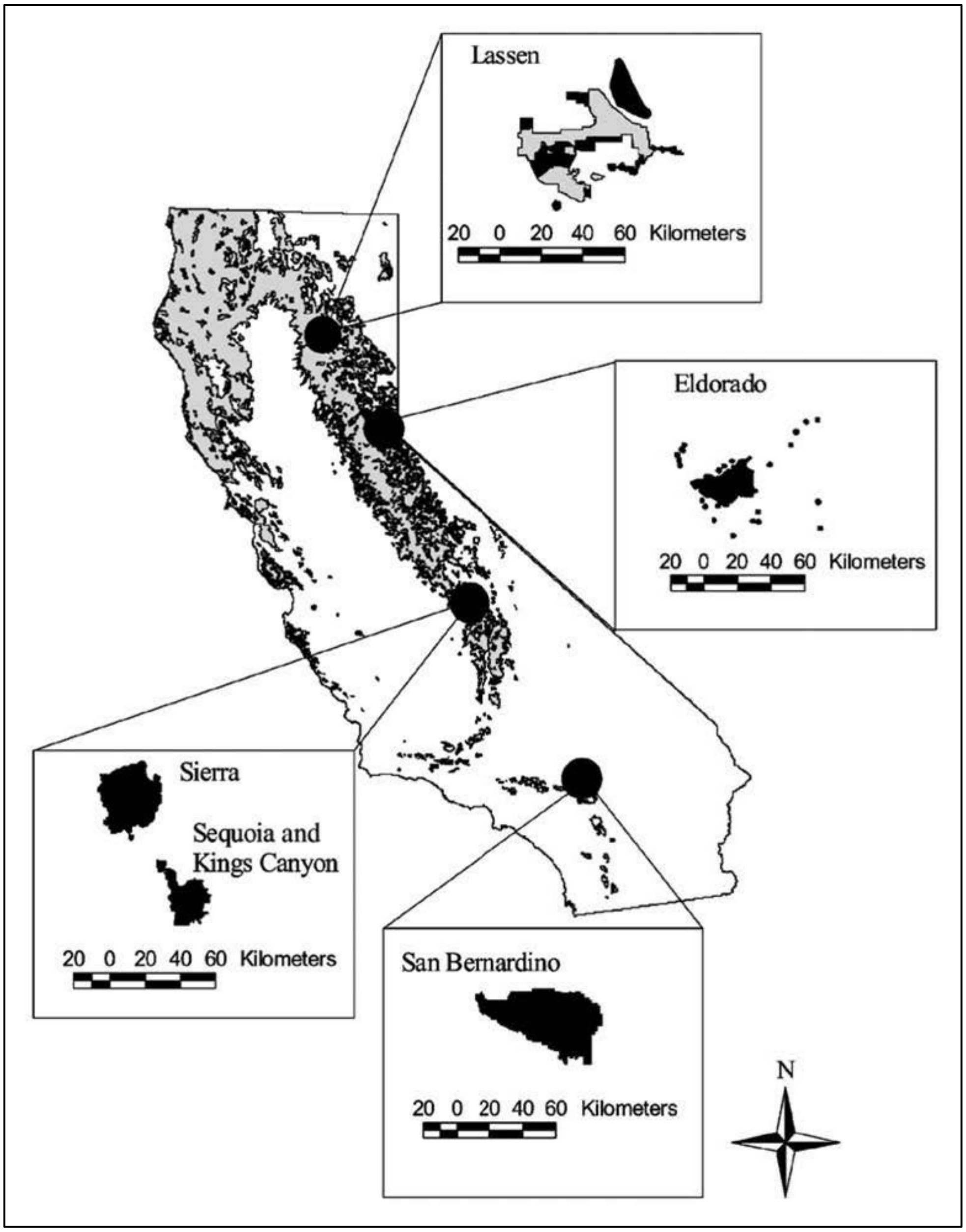

Figure 2. Locations of long-term owl studies (Figure 4-3 in Gutiérrez et al. 2017)

California Spotted Owl Habitat Use

Suitable CSO habitat, as defined in this Strategy, consists of both high-quality nesting and roosting habitat and sufficient habitat diversity/heterogeneity to provide for foraging. The highest quality nesting and roosting habitat for the CSO consists of areas with large/tall tree (more than 24 inches, but preferable more than 30 in QMD[1]) and moderate to high canopy cover (more than 40 percent cover). Suitable nest/roost/forage habitat also includes areas with medium-sized trees (11 to 24 inches QMD) and moderate to high canopy cover.

[1] QMD = quadratic mean diameter

CSO demographic parameters (that is, occupancy, reproduction, and survival) have been correlated with CSO habitat quality and availability at various spatial scales (Blakesley et al. 2005). A detailed synthesis of the research can be found in PSW-GTR-254, chapter 3 (Roberts 2017).

The majority of CSO research focuses on the relationship between CSO occupancy and the percentage of canopy cover at the territory scale. Medium (40 to 70 percent) and high (more than 70 percent) canopy cover have been positively related to CSO occupancy, survival, and productivity (Tempel et al. 2016). Ongoing research suggests CSOs select against areas of low canopy cover (less than 40 percent) within 10 acres (4 hectares) of nest sites, yet CSOs are tolerant of sparsely distributed low-canopy-cover areas in the 300 acres surrounding activity centers (“protected activity centers”) and beyond (North et al. 2017a).

An important predictor of occupancy appears to be large/tall tree-dominated habitat with dense canopy cover (Jones et al. 2017, North et al. 2017a). CSOs select for tall tree cover (more than 160 feet) and against short tree cover (less than 53 feet). North et al. (2017a) suggest density of large/tall trees is likely the most important attribute for suitable owl nesting habitat, rather than the amount of canopy cover. The large-tree category in most studies cannot differentiate between large and very large trees, as the category often includes all quadratic mean diameters (QMDs) more than 24 inches. However, correlations between diameter breast height (dbh) and tree height suggest areas of QMD greater than 30 inches are likely most important. Recent work using more fine-scale vegetation information showed owl selection for larger tree, high canopy cover habitat and selection against small and medium tree, high canopy habitat at higher elevation sites (more than 4,250 feet), and no selection preference at lower elevations (M. Raphael personal communication). North et al. (2017a) found both nest sites and protected activity centers (PACs) were dominated by tall tree and codominant structure classes, which generally coincided with more than 55 percent canopy cover, but territories and surrounding landscapes had much more diverse distributions of structure and cover classes. Gaps or openings of any size were rare in nest stands (approximately 10 acres surrounding the nest), but gaps in the PACs and territories were more consistent with the surrounding landscapes (North et al. 2017a).

For foraging, some studies suggest CSOs tend to select edge habitat (Eyes 2014, Eyes et al. 2017, Roberts 2017, Williams et al. 2011). Owls may benefit from mature forests with a mosaic of vegetation types and seral stages promoting higher prey diversity and abundance by increasing habitat diversity in foraging areas (Franklin et al. 2000, Tempel et al. 2014a, Ward et al. 1998, Zabel et al. 1995). Small open areas, areas of low canopy cover (less than 40 percent), and edges interspersed with high-quality habitat are considered important for owl foraging and habitat diversity.

New science also suggests elevation may be one of the most important predictors of CSO occupancy and reproduction, with lower elevation sites more likely to be occupied and reproductive (Hobart et al. 2019). This is likely related to habitat heterogeneity, presence of hardwoods, and increased woodrat in the CSO diet at lower elevations, among other things.

California Spotted Owl Diet

Diverse forest conditions are likely to enhance prey habitat at all elevations (Jones et al. 2016a, Sollmann et al. 2016). Woodrats (*Neotoma* spp.) and northern flying squirrels (*Glaucomys sabrinus*) make up the majority of the CSO diet by biomass. Woodrats are larger-bodied and occur at higher densities than flying squirrels and thus may be more energetically profitable CSO prey when present (Hobart et al. in review). Pocket gophers are the second most important food by biomass at all elevations (Munton et al. 2002). The CSO also consumes smaller mammals such as birds, lizards, and insects (Gutiérrez et al. 1995, Munton et al. 1997).

In lower elevations (less than 5,000 feet) in the southern Sierra Nevada, woodrats tend to dominate (74 percent by biomass) CSO diets in oak woodlands and riparian-deciduous forests (Laymon 1988, Thrailkill and Bias 1989). Woodrats often occur in habitats that are more open, oak woodlands, and early-seral-stage forests (Innes et al. 2007). The proportion of woodrats in the CSO diet appears to be lower on National Forest System lands, where studies indicate population declines, compared to SEKI, where populations appear stable (Hobart et al. in review).

Northern flying squirrels are associated with higher-elevation conifer forests (more than 5,000 feet) and comprise 46 percent of the CSO diet during the breeding season (Munton et al. 2002). Flying squirrels often occur in closed-canopy forests (Meyer et al. 2005, Pyare and Longland 2002, Roberts et al. 2015). Northern flying squirrels may select nesting or foraging sites in proximity to riparian habitat (Meyer et al. 2005, 2007) or in moist mixed-conifer stands (Meyer et al. 2005, Wilson et al. 2008). Truffles, the fruiting bodies of ectomychorrizal fungi (Meyer and North 2005), and tree hair lichen (*Bryoria fremontii*) (Rambo 2010) are the major food items of northern flying squirrels (Meyer et al. 2005, Smith 2007). Truffle diversity is also positively associated with proximity to riparian areas, which are generally characterized by wetter soils with denser vegetation (Meyer and North 2005).

Shrub patches and early-seral forest conditions at low elevations (less than 1,400 meters or less than 4,500 feet) may promote woodrat populations (Jones et al. 2016a, Wilson and Forsman 2013), while more closed-canopy, later-seral conditions may promote flying squirrel populations, and exclude woodrat populations at higher elevations (more than 4,500 feet) (Jones et al. 2016a). Increasing heterogeneity and restoring natural disturbance at higher elevations may allow for an increased proportion of woodrats in the higher elevation CSO diet.

California Spotted Owl Areas of Ecological Importance

This Strategy focuses on areas of ecological importance for meeting CSO life history requirements, including nest stand, protected activity center (PAC), territory, and home range. Table 1 provides a description of each ecological area as used in this Strategy. Figure 3 provides a conceptual model of CSO ecological areas of significance.

Table 1. CSO areas of ecological importance for the Conservation Strategy described by habitat use and habitat characteristics

Ecological Area	Habitat Use	Description	Size[1]
Nest stand	Egg development to juvenile post-fledge rearing (Whitmore 2009)	Forest stand with complex structure, high canopy cover (more than 70 percent), large trees (more than 61 centimeters [24 inches] dbh), and multiple canopy layers dominated by medium-sized trees (30 to 61 centimeters [12 to 24 inches]) (Bias and Gutiérrez 1992, Blakesley et al. 2005, Chatfield 2005, Moen and Gutiérrez 1997, North et al. 2000, Roberts et al. 2011). [2]	Approximately 10 acres surrounding a nest tree (North et al. 2017a)
Protected activity center (PAC)	Best available habitat around nest or roost in as compact an area as possible	Area a pair uses for nesting and roosting (Berigan et al. 2012, Verner et al. 1992).	300 acres (Verner et al. 1992, SNFPA[3])
Territory (a.k.a., core area)	Nesting, roosting, and foraging habitat	Area defended by a resident pair of owls from other owls of the same species (Bingham and Noon 1997, Blakesley et al. 2005, Gutiérrez et al. 1995).	800 acres (Southern Sierra) or 1,000 acres (elsewhere in the range) (Tempel et al. 2016, SNFPA[3])
Home range	Nesting, roosting, foraging, dispersal, and territorial activities	Area used by an individual to meet its life-history requirements. Often extensive overlap with other owls (Roberts 2017).	3,160 acres average (Roberts 2017)

[1]The sizes of ecological areas set forth in this table are either biological approximations, values established by management documents, or a combination of the two. The true sizes of these ecological area are likely highly variable.

[2]This description is largely derived from CSO habitat use west of the Sierra Crest; nest stand on the east side may have lower canopy cover, fewer canopy layers, or smaller trees, depending on site conditions. dbh = diameter at breast height.

[3]SNFPA= 2004 Sierra Nevada Forest Plan Amendment (USDA Forest Service 2004b)

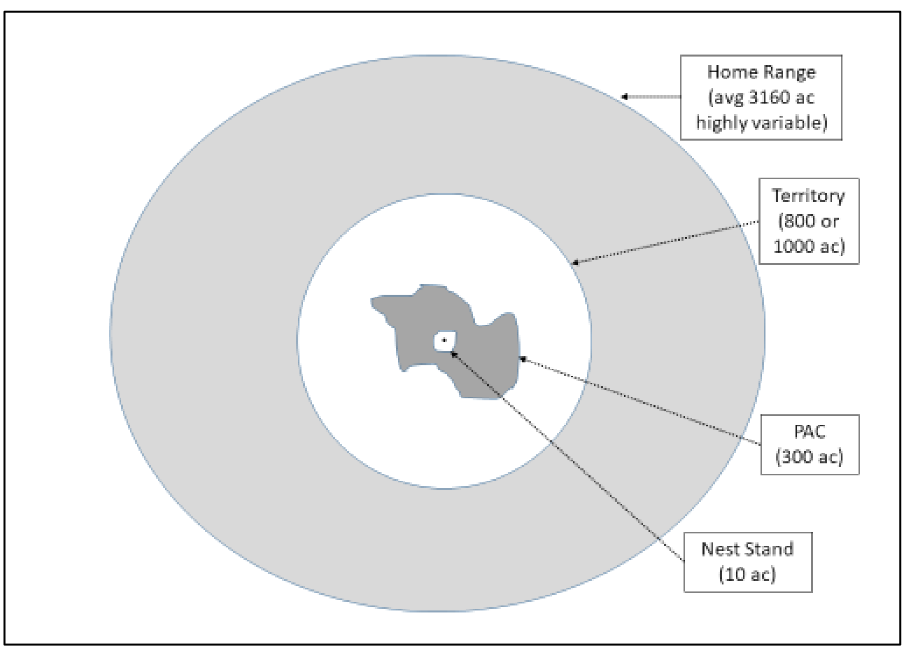

Figure 3. Conceptual model of spotted owl habitat ecological areas of significance

Nest Stand

CSOs nest in cavities, broken treetops and split tops with multiple terminal leaders, and occasionally, on platforms, such as old nests or mistletoe brooms in large conifers, oaks, and snags (Verner et al. 1992). Nest tree size varies by forest type, with mixed-conifer forests having larger and taller trees [average nest tree = 124 centimeters (49 inches dbh) and 31 meters (103 feet) tall] (North et al. 2000, Verner et al. 1992) compared to hardwoods [average nest tree = 76 centimeters (30 inches dbh) and 17 meters (55 feet) tall] (Gutiérrez et al. 1992). CSOs select strongly for nest stands with tall trees (more than 160 feet) and avoid areas with cover in small trees (less than 53 feet) (North et al. 2017). CSOs tend to avoid nest trees close to forest edges with sharp contrast, such as large trees adjacent to shrubs (Phillips et al. 2010).

Nest stands have fine-scale habitat features important for breeding, including high canopy cover (at least 70 percent), abundant large trees (more than 61 centimeters [24 inches] dbh), multiple canopy layers dominated by medium-sized trees (30 to 61 centimeters [12 to 24 inches]), and higher-than-average basal area (185 to 350 square feet per acre) (Bias and Gutiérrez 1992, Blakesley et al. 2005, Chatfield 2005, Gutiérrez et al. 1992, Moen and Gutiérrez 1997, North et al. 2000, Roberts et al. 2011, Verner et al. 1992). CSOs' selection for tall tree cover is greatest within approximately 10 acres surrounding a nest (North et al. 2017a).

Protected Activity Centers (PACs)

An active nest or suspected nest stand (based on owl territorial behavior) is referred to as an activity center. Since 1993, the USDA Forest Service (USFS) has designated a 300-acre protected activity center (PAC) around each activity center. The PAC is a USFS land allocation designed to protect and maintain high-quality CSO nesting and roosting habitat around active sites (Verner et al. 1992). PACs have been found to generally accommodate spotted owl nesting and roosting activities (Berigan et al. 2012).

The CSO exhibits high site fidelity. However, when a PAC becomes abandoned, research suggests the probability of recolonization of a vacant PAC is relatively low (0.34 one year post vacancy) and continues to decline through time. The recolonization probability is 0.20 the fourth year and 0.06 the tenth year after abandonment (Wood et al. 2018). CSO occupancy and reproduction are best predicted by previous year occupancy, and previous year occupancy and reproduction, respectively (Hobart et al. 2019), suggesting unoccupied PACs tend to stay unoccupied and, if colonized, are not reproductive the following year.

Territory or Core Area

Territorial owls, including pairs (with young), defend a geographic area consistently used for nesting, roosting, and foraging, containing essential habitat for survival and reproduction (Bingham and Noon 1997, Blakesley et al. 2005, Gutiérrez et al. 1995, Rosenberg and McKelvey 1999, Swindle et al. 1999, Williams et al. 2011). A territory has also been referred to as a core use area (Swindle et al. 1999). Scientists in the central Sierra Nevada have defined the core area as a radius equal to half the mean-nearest-neighbor distance between the centers of adjacent owl sites. This equates to a distance of 1.1 kilometers (0.7 miles) and an area of 400 hectares (1,000 acres) (Jones et al. 2017, Seamans and Gutiérrez 2007, Tempel et al. 2014a). For this Strategy, territory size is 800 acres in the southern Sierra national forests (Inyo, Sierra, and Sequoia) and 1,000 acres in the north and central Sierra Nevada national forests to align with core use areas (Tempel et al. 2016). A territory includes the associated PAC.

Home Range

A CSO home range includes the PAC, the associated territory, and additional areas to meet the CSO life-history requirements. CSOs establish large home ranges averaging 3,160 acres or 1,279 hectares (Roberts 2017). Home range sizes are highly variable (1,500 to 5,400 acres or 634 to 2,195 hectares), and estimates vary by study, latitude, elevation, diet, and individual.

Section 4. Threats

Large, High-Severity Wildfire

Large, high-severity wildfire threatens CSO persistence across the landscape (Peery et al. 2019, Stephens et al. 2016b). A century of fire exclusion has resulted in an ingrowth of shade-tolerant (fire intolerant) trees and an accumulation of surface and ladder fuels, increasing both amount and patch size of high-severity fire in the Sierra Nevada low- and mid-elevation conifer forest types (Mallek et al. 2013, Miller et al. 2009, Steel et al. 2015). Currently, many Sierra Nevada forests are dense and homogenous (Hessburg et al. 2005), with high vertical and horizontal fuel continuity; these conditions are conducive to high-severity fire. Recent examples of large, high-severity wildfires overlapping CSO habitat are the 2013 Rim Fire (250,000 acres) and the 2014 King Fire (100,000 acres). From 1993 to 2016, approximately 450,000 acres of forest within the CSO range of the Sierra burned at high severity. Over the same period, approximately 125,000 acres (22 percent) of owl PACs burned across the range, and 32 percent of the burned area was high severity (Keane and Gerrard unpublished update to Keane 2017). Trends in high-severity fire proportion and patch size are likely to continue to increase in the absence of active forest restoration (Stephens et al. 2016a).

Owls likely benefit from low, moderate, and a mixture of fire severities, with smaller high-severity fire patches and edges that create forest heterogeneity (Lee et al. 2012, 2013; Lee and Bond 2015b; Roberts et al. 2011); however, neither the optimal mix of severity patches nor the optimal spatial configuration of vegetation is known (Keane 2017). As fire size and the proportion of high-severity fire increases, so does the area within large high-severity patches (Miller et al. 2009). Large, high-severity patches are linked to decreases in spotted owl occupancy, colonization, and habitat use (Eyes 2014, Eyes et al. 2017, Roberts et al. 2011, Tempel et al. 2014a) and increases in owl extinction probability (Lee et al. 2013). Jones et al. (2016b) showed occupancy of severely burned territories declined substantially, and severely burned areas were avoided by owls, even when foraging. Where greater than half of a territory burned at high severity, territory extinction rates went up seven times, and predicted occupancy declined nine-fold from pre-fire values (Jones et al. 2016b). Stephens et al. (2016b) has predicted, based on modeling data, that within the next 75 years, high-severity fire will continue to be a threat to CSO habitat, and the cumulative amount of nesting habitat burned at high or moderate-to-high severity (more than 50 percent basal area mortality) will exceed the total amount of habitat existing today.

Wildfire is highly variable in nature and so is the response of spotted owls to wildfire effects (Rockweit et al. 2017). Each wildfire has a unique set of factors (for example, pre-fire habitat conditions, time since last fire, overall burn severity, size) and methodologies scientists deploy to analyze owl response (for example, occupancy, demography, habitat use). Patterns of high-severity burn in some fires may increase forest heterogeneity and structural complexity by providing more remnant live trees suitable for owls (for example, Lee and Bond 2015a) while others are more homogeneous and more negatively impact owl sites (for example, Jones et al. 2016b).

Forest Management

The effects of specific forest management activities on spotted owls are not well understood (Gutiérrez et al. 2017, U.S. Fish and Wildlife Service 2011). Research conclusions have been mixed on the magnitude and duration of both negative and beneficial impacts to owl habitat suitability and owl populations from forest management activities.

Complex forest management involving multiple treatments, combined with small sample sizes, makes drawing conclusions about the effects of an individual management activity type untenable. An example is the Seamans and Gutiérrez (2007) study (monitored 66 owl territories from 1990 to 2004), which concluded the probability of occupancy declined 2.5 percent when habitat alteration occurred in more than 50 acres (20 hectares) within a territory. The results in Seamans and Gutiérrez (2007) study have several limitations: (1) habitat treatments were caused by various types of management (for example, clearcutting, thinning, other prescriptions, fire), and specific impacts of different disturbance types could not be examined independently (for example, logging versus fire); (2) dispersing owls did not necessarily select new territories with higher-quality habitat, as only 53 percent of dispersing owls switched to a territory with higher expected survival; and (3) the authors suggest selection of new territories by breeding individuals was not correlated with mature conifer forest (more than 12 inches dbh and more than 70 percent canopy cover) but may have been associated with mate selection. Stephens et al. (2014) showed the number of occupied CSO territories declined, from 7 and 9, before and during implementation of vegetation treatments (2002 to 2007) to four territories 3 to 4 years after treatments were completed, though longer-term impacts or benefits are unknown. This study had a small sample size, and did not compare these patterns to the declines in the surrounding untreated landscape, making general inferences difficult.

Tempel et al. (2014a and 2016) investigated owl behavior in an area that included the Seamans and Gutiérrez study area but occurred over a longer period and a larger geographic area. Tempel et al. (2014a) found mixed results related to the effect of medium-intensity timber harvest[2] on owls but noted actions that converted mature conifer forest from high canopy cover (more than 70 percent) to lower canopy cover (less than 70 percent) were negatively correlated with demographic parameters. However, the authors found high-intensity timber harvest (for example, clearcutting) appeared to have a weak beneficial effect on owls, likely due to the creation of edges (Tempel et al. 2014a). These studies did not detect a clear adverse impact on owls from timber harvest. Similarly, Irwin et al. (2015) found most harvests had no detectible effect on spotted owls, and the authors did not detect any site abandonment of occupied territories when less than 58 percent of an area was treated.

[2] Medium-intensity harvest was defined by the authors in this paper to include group selection, selection, single-tree selection cut, thinning for hazardous fuels reduction, fuel break, and commercial thin.

The lack of impacts detected in these studies may be partially because forest management practices since the early 1990s have not reduced the amount of high-quality habitat found to be most important in determining occupancy over time (Jones et al. 2017). J.D. Wolfe and J.J. Keane (personal communication) were unable to assess effects of logging across the demographic studies over multiple decades because the number and amount of territories affected were so small. Tempel et al. (2016) concluded forest thinning in CSO territories may maintain habitat quality in the short term and also provide long-term benefits to the species. The authors state: "forest treatments that reduce canopy cover within spotted owl territories, if judiciously implemented, could maintain Spotted Owl habitat in the short term so that any long-term benefits as a result of reductions in high-severity fire can be realized." As the CSO avoid cover in smaller trees (less than 53 feet tall), treatment or harvest that reduces these potential ladder fuels likely maintains or improves owl habitat in both the short and long term (North et al. 2017a).

Mosaic habitats created by mixed-severity prescribed or managed fire likely provide benefits to the CSO (Eyes et al. 2017; Lee et al. 2012, 2013; Roberts et al. 2011, 2015), while management that creates wide swaths of homogenous open habitat decreases habitat quality and increases avoidance by owls in the near term (Stephens et al. 2014). Similarly, habitat homogenization and densification due to fire suppression has also likely caused, and continues to cause, habitat loss for the CSO (Gutiérrez et al. 2017, Verner et al. 1992).

Timber harvesting on private lands in the CSO range typically uses even-aged management, like clearcutting, which may reduce spotted owl habitat quality by reducing or eliminating critical habitat elements: high canopy cover and old, large-diameter trees and associated large downed logs (Gutiérrez et al. 2017, McKelvey and Weatherspoon 1992). Recent studies suggests the CSO may occur on private timberlands at a greater density than expected, despite these areas having higher harvest rates (Atuo et al. 2018, Roberts et al. 2017). Roberts et al. (2017) indicate CSO occupancy did not decline over time despite extensive harvest. In other studies, CSOs have been observed avoiding private lands, presumably because of a lack of key habitat elements (Bias and Gutiérrez 1992). Additional work is still required to determine habitat quality on private lands, their contribution to the viability of the regional CSO population, and the long-term effects of even-aged harvest systems.

Collectively, studies of forest management impacts on CSO habitat and demography suggest there may be tradeoffs in the near term in habitat quality for long-term habitat sustainability, particularly as climate change increases the frequency and severity of habitat disturbances (Stephens et al. 2016b; Tempel et al. 2015, 2016). While forest management that increases heterogeneity and resilience to disturbance may benefit the CSO (Gutiérrez et al. 2017, Jones et al. 2016b, Roberts et al. 2015, Tempel et al. 2016), management that maintains or increases homogeneity or decreases the amount of large/tall tree habitat may come at a near-term cost to current spotted owl occupancy (Stephens et al. 2014). Potential near-term costs of density- and canopy-reduction treatments may be minimized by maintaining or increasing the highest quality large-tree habitat (Wood et al. 2018) and may be balanced by long-term gains when treatments result in increased persistence/sustainability of habitat elements over time (Jones et al. 2017; Stephens et al. 2014; Tempel et al. 2014a, 2015). Balancing these tradeoffs, and promoting management activities that will maintain or increase key owl habitat elements in more sustainable locations in the future, will require site-specific analyses combined with landscape-level planning.

Tree Mortality (related to drought and insects)

Extensive drought- and insect-related tree mortality threatens CSO habitat, especially the large trees owls depend upon for nesting and roosting. Recent drought in dense forests has led to severe water stress (Asner et al. 2015, Young et al. 2017), which in turn attracts insects (bark beetles) and increases risks from pathogens and air pollution.

CSO habitat overlaps with the western pine beetle, mountain pine beetle, Jeffrey pine beetle, pine engraver beetle, and fir engraver beetle. Depending on the bark beetle species and numerous other factors (Fettig et al. 2007), the extent of tree mortality may be limited to small groups of trees or it may impact extensive areas. Outbreaks occur when favorable forest and climatic conditions coincide, and climate change is likely exacerbating bark beetle impacts (Bentz et al. 2010). Warming temperatures have triggered population increases in many insect species, which have resulted in widespread outbreaks (Millar and Stephenson 2015). Bark beetle infestations are influenced by factors such as overall stand density, tree diameter, tree vigor, fire exclusion, and host species density. Slower-growing ponderosa pines (which are more fire tolerant than other mixed-conifer species) are more susceptible to attacks than other species (Craighead 1925, Miller 1926). Various measures of stand density, including stand density index or basal area, are positively correlated with levels of tree mortality from bark beetles (Fettig et al. 2012, Hayes et al. 2009).

Since 2012, there has been a dramatic increase in loss of large trees due to bark beetles in low- to mid-elevation coniferous forests of the southern Sierra Nevada. There, the western pine beetle, which is considered one of the principal agents of tree mortality in the Sierra Nevada (Fettig 2012, 2015), has had a widespread impact on ponderosa and sugar pines (USDA Forest Service 2017b). The synergistic effect of high tree densities, coupled with drought, insects, pathogens, and air pollution, is increasing tree mortality at landscape levels. Expected background levels of tree mortality in the mixed-conifer habitat are roughly less than one tree per three acres (USDA Forest Service 2017a). Between 2014 and 2017, tree mortality levels increased more than 100 fold in many areas of the southern Sierra (USDA Forest Service 2017a). During this period, 55 percent of the PACs on the southern Sierra national forests (Sierra, Sequoia, and Stanislaus) experienced tree mortality of more than 20 trees per acre (USDA Forest Service 2017a), with greater loss in larger-diameter trees. Prevention strategies for minimizing further habitat loss by reducing water stress and competition will be critical to CSO habitat conservation.

Climate Change

Climate models project increasing temperatures in California, ranging from increases of 2 to 9 degrees Fahrenheit by the end of century, with the greatest increases during summer (Dettinger 2005, Hauptfeld et al., 2014, Hayoe et al. 2004). Modeled estimates for the Sierra Nevada indicate temperatures will increase by 5.4 to 10.8 degrees Fahrenheit (3 to 6 degrees Celsius) during the twenty-first century. Models also suggest a larger percentage of precipitation occurring as rain rather than snow, and a 64 to 87 percent decline in snowpack. An increase in year-to-year variability in precipitation is also projected (Hauptfeld et al. 2014).

Increases in temperature and changes in precipitation patterns may impact the CSO in the following ways:

- direct, physiological effects on individuals
- alterations to prey communities, interactions with predators and competitors, and disease dynamics
- changes in habitat quantity, quality, and distribution

In some parts of the spotted owl range, drought and high temperatures during the previous summer have been linked to lower spotted owl survival and recruitment the following year (Franklin et al. 2000, Glenn et al. 2011, Jones et al. 2016a). Decreases in precipitation, and associated moisture stress, may reduce production of plants, seeds, and fungi that are important food for CSO prey (Glenn et al. 2010, 2011; Olson et al. 2004; Seamans et al. 2002). Impacts to CSO populations are likely to be complex. Warm, dry springs tend to increase reproductive success, and spotted owls have population-specific responses to regional climate and weather patterns (Glenn et al. 2010, 2011; Jones et al. 2016a; Peery et al. 2012).

Climate change projections indicate many of the low- and mid-elevation forests that currently comprise CSO habitat in the Sierra Nevada are vulnerable to conversion to woodlands, shrublands, and grasslands. Recent drought (2012 to 2015) led to extensive mortality of trees in CSO habitat, and the extent of the impacts are largely unknown (Asner et al. 2015). Pines have experienced the most mortality since 2014, with more than a hundred million dead trees mapped by the USFS as a result of the 4-year drought and subsequent beetle outbreak (Safford and Stevens 2017, page 85).

Projected increases in temperature and decreases in snowpack for the Sierra Nevada (Safford et al. 2012) are likely to continue the increasing trend in the size of stand-replacing fires and proportion of landscape impacted by high-severity fires (Stephens et al. 2013). In the long term, these threats may be somewhat mitigated by mixed-conifer forests moving upslope and the development of habitat for CSO where none now exists (Peery et al. 2012). However, development of suitable forest structure at higher elevations may take hundreds of years and may not keep pace with habitat loss at lower elevations (Stephens et al. 2016b).

Barred Owls

Barred owls have invaded western North America over the past century (Livezey 2009), posing a significant threat to the viability of the northern spotted owl (Gutiérrez et al. 2007, U.S. Fish and Wildlife Service 2011, Weins et al. 2014, Yackulic et al. 2019). Barred owls are aggressive competitors and have overlapping habitat and diet with spotted owls (Hamer et al. 2001, 2007; Wiens et al. 2014). Both species prefer mature forest habitat with large trees and high canopy closures (Hamer et al. 2007, Singleton et al. 2010, Wiens et al. 2014); however, barred owls will use a broader suite of vegetation types (Hamer et al. 2007, Wiens et al. 2014). Both species prey on small mammals, although barred owls consume a wider variety of terrestrial and aquatic prey (Hamer et al. 2001, Wiens et al. 2014).

Barred owls are competitively superior to spotted owls by producing more young and supporting two- to four-times higher population densities in smaller home ranges (Hamer et al. 2007, Singleton et al. 2010, Wiens et al. 2014). When barred owls are present, northern spotted owls (NSO) have greater territory extinction probabilities and lower colonization probabilities (Dugger et al. 2011, Dugger et al. 2016, Olson et al. 2005, Yackulic et al. 2014,), lower nest success (Wiens et al. 2014), and lower probability of habitat use (Van Lanan et al. 2011).

A barred owl was first detected in the northern Sierra Nevada in 1989 and in the central and southern Sierra in 2004 (Steger et al. 2006). In 2013, eight barred owls and two sparred owls (spotted owl-barred owl hybrids) were detected on the Lassen demographic study area (figure 4). As of 2013, there have been 51 barred owls detected in the Sierra Nevada (Keane 2017). As of 2017, there were over 140 barred owl detections recorded in the California Natural Diversity Database, although these records do not necessarily reflect unique individuals (U.S. Fish and Wildlife Service 2017). The first systematic barred owl surveys for the Sierra Nevada were conducted in 2017 on the Lassen and Plumas National Forests. Between 2017 and 2018, barred owl site occupancy rose from 0.07 to 0.22 in this area, indicating rapid population growth (Wood et al. unpublished data). If control measures were to be implemented, they would be more likely to be successful now, while the densities of barred owls are still low in the CSO range (Dugger et al. 2016).

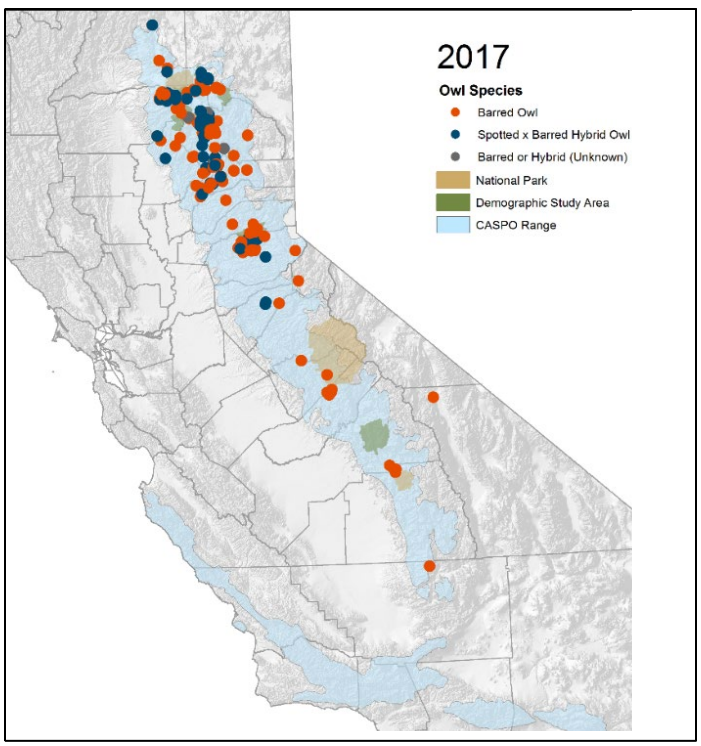

Figure 4. Barred owl and sparred owl records within the range of the California spotted owl in the Sierra Nevada, 1989 to 2017 (Keane unpublished update to Keane 2017)

In the range of the NSO, ongoing barred owl removal experiments conducted in areas of relatively high barred owl densities suggest the NSO may reoccupy a site within one year after barred owl removal; however, 1 to 4 years after the initial removal, barred owls again occupied some sites (Diller et al. 2014). Detection of barred owls in the range of the CSO have been broadly distributed at low densities, with higher densities at higher latitudes. This suggests the edge of barred owl expansion is concentrated at the northern end of the CSO range.

Noise Disturbance

Noise associated with nonmotorized recreation does not seem to pose a threat to spotted owls. Mexican spotted owls exhibited low behavioral responses of any type to hikers who were at least 55 meters (more than 180 feet) away, and juveniles and adults were unlikely to flush from hikers at distances more than 12 or more than 24 meters (more than 39 or 78 feet), respectively (Swarthout and Steidl 2001). Additionally, owls did not change their behavior when hikers were near nests, although cumulative effects of high levels of recreational hiking near nests are unknown (Swarthout and Steidl 2003). Potential effects of off-road motorized recreation are unknown.

Chainsaws and helicopter noises do not appear to decrease reproductive success (Delaney et al. 1999) nor increase stress hormones like corticosterone (Tempel and Gutiérrez 2003, 2004). Delaney et al (1999) found no difference in Mexican spotted owl reproductive success when owls were exposed to helicopter and chainsaw noise. Tempel and Gutiérrez (2003, 2004) found no hormonal or behavioral responses of male California spotted owls exposed to chainsaw activity roughly 330 feet (100 meters) from their roost site. Behavioral responses of owls (flushing) occurred only when helicopter or chainsaw disturbance was within roughly 350 feet (105 meters) of the nest and only after young had fledged. Delaney et al. (1999) also found effects to prey delivery rates occurred when disturbance was within roughly 315 feet (96 meters) of the nest and observed alert behavior when helicopters averaged roughly 1,300 feet (403 meters) above the nest. Collectively, these studies suggest chainsaw activity or helicopter flights, particularly 100 meters (or roughly 300 feet) or more from nest sites, have very little potential to impact the CSO.

Hayward and others (2011) found NSOs closer (less than 100 meters) to low-noise-level roads actually fledged more young than those further away (likely due to increased prey availability around roads), while owls closer to high-noise-level roads fledged fewer young than those further away (likely due to the chronic stress of continuous traffic noise). Wasser and others (1997) reported higher stress levels (indicated by fecal corticosterone) in male NSOs within one quarter of a mile (0.41 kilometers) of a major logging road or recent timber harvest than those further away, but no differences in female hormone levels were found. The authors did not examine hormonal differences relative to distances within a quarter mile of the roads. Hayward et al. (2014) found NSOs exhibit more stress when exposed to motorcycle activities and exhibit lower reproductive success when exposed to busy roads. Tempel and Gutiérrez (2004) found no effect of road proximity on fecal corticosterone levels in CSOs. Hayward et al. (2011) also did not detect an association between hormone levels and distance to roads, though they observed increased hormone levels with acute (1-hour) exposure to traffic noise, particularly in males during the early breeding season (May). Taken together, these studies suggest there may be both benefits and costs associated with roads for the CSO, and additional research is needed on if and when road activity negatively impacts owl survival or reproduction. Distance effects are likely site specific and road-type specific, as well as sex specific, and depend greatly on traffic level, among other things.

Contaminants

Environmental contaminants, particularly anticoagulant rodenticides associated with marijuana cultivation, are an emerging threat to the CSO. While CSOs have not yet been tested for exposure to rodenticides, studies indicate that 85 to 100 percent of fishers (*Pekania pennanti*), 40 percent of barred owls (of 84 tested), and 70 percent of NSOs (of 10 tested) have experienced exposure (Gabriel et al. 2018, Gutiérrez et al. 2017, Thompson et al. 2017). Given that CSOs share similar habitats and prey with fishers and NSOs, they are also likely to be affected by rodenticides (Gutiérrez et al. 2017). Barred owls eat a wider diversity of prey than spotted owls, which may serve to dilute their exposure to anticoagulant rodenticides (Gabriel et al. 2018). Monitoring studies on other raptor and owl species indicate lethal and sublethal impacts of anticoagulant rodenticides exposure (CA Department of Fish and Wildlife [CDFW] 2016). CDFW's Wildlife Investigation Laboratory has found raptors comprise two-thirds of the anticoagulant-related wildlife mortalities submitted (CDFW 2016). Available information has shown exposure either decreases fitness or increases mortality from what would normally be considered a benign injury (Gabriel et al. 2018). Studies have linked exposure to reduced clutch size, reduced brood size, reduced fledging success, slower clotting time, and contaminant transfer to eggs (Gabriel et al. 2018). In addition, given differential exposure rates, contaminant impacts may serve as yet another factor favoring barred owls competitive advantage over spotted owls.

Section 5. Current Conditions Relative to Historic Conditions

McKelvey and Johnston (1992) highlight four key changes in forests as compared to historic or NRV conditions: (1) loss of old, large-diameter trees and associated large downed logs; (2) shift in tree species composition towards shade-tolerant species; (3) increase in fuel associated with mortality of smaller trees; and (4) presence of ladder fuels that facilitate crown fire. Similarly, Franklin and Johnson (2012) outline four significant changes seen in fire-prone or dry mixed-conifer forests relative to NRV: (1) fewer old trees of fire-resistant species, (2) denser forests with multiple canopy layers, (3) more densely forested landscapes with continuous high fuel levels, and (4) more stands and landscapes highly susceptible to stand-replacement wildfire and insect epidemics. Key drivers of these changes include historic logging and over a century of fire suppression, as well as climate change.

Relative to NRV, there are fewer large, old trees in the Sierra Nevada today, and there has been a decrease in both average tree size and maximum tree size (Collins et al. 2017, Dolanc et al. 2014). Trees greater than 36 inches in diameter at breast height (dbh) have declined in abundance, trees 24 to 36 inches dbh have decreased in some places and increased in others, and trees less than 24 inches dhb have increased (Collins et al. 2017, Dolanc et al. 2014, Fellows and Goulden 2008, Lutz et al. 2009, McIntyre et al. 2015, North et al. 2007, Scholl and Taylor 2010, Stephens et al. 2015, Verner et al. 1992). Compared to historic forests, the average tree size has declined 60 percent and 26 percent in the Lake Tahoe Basin Management Unit and Stanislaus National Forest, respectively (Lydersen et al. 2013, Taylor et al. 2014). While timber harvest and tree planting explain some of the shift from larger to smaller trees, similar patterns also occur in unlogged forests, suggesting other factors exist, such as insects, pathogens, and drought stress that are likely exacerbated by higher stand densities in modern forests (Safford and Stevens 2017, page 101).

Following the release of Verner et al. (1992) and the associated CASPO Interim Guidelines (USDA Forest Service 1993)*,* the USFS dramatically reduced timber harvest operations in the range of the CSO, shifting forest management to commercial thinning, salvage logging after wildfire, and hazard tree removal (North et al. 2017). From 1994 to 2013, 83.4 percent of timber volume harvested came from private lands and 10 to 25 percent from public lands (North et al. 2017b).

Sierran mixed-conifer forests today have high stand densities and altered species compositions, compared to historic conditions. Shade-intolerant and fire-resistant pine trees are decreasing, while shade-tolerant species, such as firs and incense cedars, are increasing in abundance (Barbour et al. 2002, Dolanc et al. 2014, Guarin and Taylor 2005, McIntyre et al. 2015, Stephens et al. 2015). Modern tree densities have increased compared to historic conditions (Ansley and Battles 1998; Barth 2014; Beaty and Taylor 2007, 2008; Dolanc et al. 2014; Knapp et al. 2013; Taylor et al. 2014) and continue to increase, primarily in small- and medium-sized trees (Safford and Stevens 2017, pages 97 to 99). Increases in forest density range from 80 percent to 600 percent, with most of this increase in trees less than 24 inches (60 centimeters) dbh (Safford and Stevens 2017, page 97).

Landscape-scale conditions under NRV had a patchwork of relatively open canopy over the majority of the landscape, interspersed with early seral and closed canopy areas (Safford and Stevens 2017, page 90). Current conditions represent an increase in average canopy cover of around 25 percent relative to historic conditions (Stephens et al. 2015). Tree canopy cover averages about 33 percent more today than in the presettlement period (Safford and Stevens 2017, page 177). An increase in canopy cover may have benefited CSO in some locations by creating potential nesting and roosting habitat where it would not have existed historically (for example, in more xeric microclimates) but may have negatively impacted the CSO by increasing the area of high cover of the small-to-medium tree habitat they tend to select against (North et al. 2017a).

Fire exclusion has resulted in an estimated 2.9 million acres of ‘backlogged’ forest in need of treatment (North et al. 2012). Today’s disrupted fire regimes in the Sierra Nevada include lower amounts of low- and moderate-severity fire and more large, high-severity, stand-replacing fires that destroy large blocks of important CSO habitat. Fires burning in CSO habitat in the Sierra Nevada are burning 85 percent less frequently than historically. The current average fire size (excluding those immediately put out) is 5 times greater, and high-severity fire is burning 5 to 7 times more area than historically (Safford and Stevens 2017, page 180). Historic fire regimes would have allowed about half of all forested area to reach late succession, providing substantial suitable habitat for the CSO (Miller and Safford 2017). Given CSOs use mixed-severity fire areas dominated by low and moderate severity and generally avoid larger areas of high severity, the historic fire regime was likely beneficial to the species (Eyes et al. 2017; Jones et al. 2016b; Lee et al. 2012, 2013; Roberts et al. 2011; Rockweit et al. 2017).

Fire exclusion has also resulted in increases in snag density, coarse woody debris, litter and duff depth, and surface fuel volume and continuity (Safford and Stevens 2017, page 8); these changes have contributed to the increase in the occurrence of large, high-severity fire (Safford and Stevens 2017, page 91). Snag densities and coarse woody debris (CWD) are more abundant in modern forests than in average presettlement forest stands (Safford and Stevens 2017, page 180). CWD is a contributor to forest fuels and fuel loadings, and in yellow pine and mixed-conifer forests, fuel loadings have risen, on average, 70 to 100 percent over the past century (Safford and Stevens 2017, page 180). This compromises forest resiliency to large-scale, high-severity fire.

Tree mortality rates during recent drought have also been shown to be positively correlated with increased tree density (Young et al. 2017). Increased tree mortality in the Sierra Nevada has been attributed to climate change, drought, and water stress (Fellows and Goulden 2008, Lutz et al. 2009, McIntyre et al. 2015) and partially related to increased tree densities, interacting with multiple other factors, including pathogens, insects, and air pollution (Das et al. 2011, Guarin and Taylor 2005, McIntyre et al. 2015, Smith et al. 2005).

Currently, deficiencies in very large, old trees; a lack of forest diversity/heterogeneity; and limited seral-stage variation are compromising CSO habitat resiliency. A summary of references of NRV conditions of yellow-pine and Sierran mixed-conifer forests can be found in PSW-GTR-256 (Safford and Stevens 2017, pages 177 to 181; table 11, pages 178 and 179).

The Role of Natural Range of Variation in the Strategy

Promoting forest restoration toward the natural range of variation (NRV) is a central and guiding principle of this Strategy. NRV-based management will serve the Strategy's two core habitat goals: (1) the maintenance and creation of key habitat elements and (2) the resilience of habitat to natural disturbances and climate change. NRV provides quantitative values for a range of conditions derived from studies in contemporary reference landscapes and from historic information sources. Historic CSO abundance and density estimates are unknown; however, the NRV in which the CSO has evolved and persisted in Sierran mixed-conifer forests is well understood and provides a reference for developing conservation actions for this Strategy.

Moving CSO habitat toward NRV conditions provides benefits to the CSO. Restored forests provide the range of conditions in which the species evolved and survived prior to European settlement. Restored forests are more heterogeneous and resilient to many disturbances, such as large-scale, high-severity fire; insects; disease; drought; and climate change. Restoring forest composition, structure, and processes based on NRV conditions is linked to greater resilience to wildfire, climate change, and other stressors (Kalies and Kent 2016, Larson et al. 2013, Stephens et al. 2016a).

NRV values are influenced by fine-scale local site characteristics (for example, topographic position, soil type, latitude, longitude, elevation, aspect, vegetation type) and dynamic natural disturbance regimes (for example, fire, insects, disease, drought, windthrow, landslides), and these same traits create the context for forest management actions. For example, dry, low-productivity sites on ridgetops or south-facing slopes on the west side of the Sierra Crest may be most appropriately managed toward the lower end of NRV for tree density and cover. In contrast, a highly productive, wetter, west-side site in a valley bottom with less frequent fires may be most appropriately managed toward the higher end of NRV for tree density and cover. Given projections of future climatic conditions, NRV values should not be used as a targeted endpoint but rather as a starting point for movement towards a future range of variation. The future range of variation is an emerging concept and reference models can be applied as they become available (Haugo et al. 2015).

For a list of variables and their influence on NRV for yellow pine and mixed-conifer forests in the Sierra Nevada, refer to Safford and Stevens 2017, table 11, pages 178 and 179. The values derived from this and other references largely apply to habitats on the west side of the Sierra Crest. Appropriate values for habitat on the east side and drier forest types may fall outside the ranges described in this Strategy. For information on amounts of CSO habitat in different forest types by national forest, see tables 5.6 (page 124) and 5.7 (page 125) and 5.8 (page 126) in Gutiérrez et al. 2017.

Section 6. Desired Conservation Outcomes

The desired conservation outcomes for the Strategy include:

- Suitable habitat is well distributed and sufficient to support sustainable owl populations. Habitat is resilient to disturbances and climate change, considering NRV and recognizing the Sierra Nevada forests are dynamic ecosystems that will support a range of vegetation types and structures that vary over space and time.
- California spotted owl populations are maintained or enhanced throughout their historic range across the Sierra Nevada forests. California spotted owl populations are maintained across the range as habitat is transitioned to be more resilient and as ecosystems in the Sierra Nevada are transitioned from the current situation towards NRV and eventually towards the future range of variation.
- Non-habitat threats to California spotted owl are minimized.

To achieve these conservation outcomes, this Strategy recommends measures to:

- maintain occupancy of currently occupied CSO activity centers by maintaining high-quality habitat, especially around occupied nest sites, while developing resilient habitat across the landscape
- develop CSO habitat to support abundant, dynamic, and resilient/sustainable activity centers across heterogeneous landscapes
- manage CSO habitat in an adaptive framework to address existing scientific uncertainty and changing conditions
- minimize non-habitat threats to the CSO

Section 7. Goals and Objectives

Goals and objectives are developed to meet desired conservation outcomes.

Goals 1 and 2 are habitat based and will be facilitated by restoration towards NRV. Goal 1 includes near-term habitat retention objectives to provide stability to individual owls as the landscape transitions toward NRV and longer-term habitat development objectives to facilitate CSO population sustainability. Goal 2 includes immediate and longer-term habitat restoration and resilience objectives. The Strategy recognizes a tension between aspects of these two goals, which will require site-specific conservation decisions and adaptive management as the landscape evolves. Goal 3 is population based, and objectives will be facilitated by science-management partnerships.

Goal 1. Promote and maintain well-distributed California spotted owl habitat by retaining and developing key habitat elements and connectivity.

- **Objective A.** Maintain and promote nesting, roosting, and foraging habitat in occupied and future territories.
- **Objective B.** Maintain and promote high canopy cover in large/tall trees for nesting and roosting at all spatial scales (PAC, territory, and home range).
- **Objective C.** Maintain and recruit large/tall, old, and structurally complex trees and snags.
- **Objective D.** Retain dense tree clusters and clumps of multi-storied tree canopies, interspersed with small gaps at the stand/patch scale.
- **Objective E.** Minimize the risk of habitat loss associated with altered disturbance processes, including altered fire regimes, drought, and increased bark beetle outbreaks.
- **Objective F.** Maintain and promote preferred prey populations by promoting habitat characteristics to meet California spotted owl dietary needs.

Goal 2. Promote California spotted owl persistence by increasing the resilience of existing habitat and facilitating the development of additional, resilient habitat.

- **Objective A.** Use NRV to inform land management that promotes resilient habitat.
- **Objective B.** Increase habitat diversity and complexity at multiple scales (substand to landscape).
- **Objective C.** Restore composition, pattern, and structure of understory and overstory vegetation to make forests healthier and more sustainable.
- **Objective D.** Develop large trees on the landscape, while decreasing intermediate- and small-sized trees, to promote more resilient trees and landscapes.
- **Objective E.** Allow natural disturbance dynamics to shape and maintain resilient forests.
- **Objective F.** Foster climate adaptation of California spotted owl habitat.

Goal 3. Maintain a well-distributed and stable California spotted owl population across the species' range by minimizing impacts from non-habitat threats, like barred owls and rodenticides.

- **Objective A.** Identify California spotted owl mortality and disturbance causes, determine the best mechanisms for addressing these factors, and reduce mortality and disturbance risk factors.
- **Objective B.** Study potential mechanisms to prevent barred owls from reaching the critical density that would allow exponential expansion of their range and abundance, and use study results to develop a threat reduction plan.

Section 8. General Considerations for Conservation Approaches and Measures

Conservation approaches and measures are designed to achieve goals, objectives (section 7), and desired conservation outcomes (section 6). Conservation measures are recommendations designed to inform management decisions and are not meant to provide a one-size-fits-all solution that must be uniformly applied in all instances. Rather, the context of local conditions, new information, and a changing climate should be considered when implementing and adjusting conservation measures, using the best available scientific information and local knowledge. The general considerations for the recommended conservation measures are described in this section; the specific recommended conservation measures are listed in section 9, under each of the applicable approaches.

Site Specificity

When planning and implementing conservation measures in CSO habitat at any scale, consider site conditions and productivity (topographic position, soil type, elevation, aspect, vegetation type, moisture), natural disturbance regimes (fire, insects, disease, drought, windthrow, landslide), and local knowledge. For example, land managers should consider potential effects of natural fire regimes based on moisture and soil productivity. Openings are likely to be larger and more frequent on low-productivity, dry, south-facing slopes and ridgetops while being smaller and less frequent in high-productivity, moist valley bottoms. Wetter, more productive sites are more sustainable locations for high-quality CSO habitat rather than drier areas, particularly those with higher mean annual climatic water deficit (Young et al. 2017). Low-productivity sites and dry sites are likely to support fewer large to very large trees and snags than higher-productivity and wetter sites, though patterns vary throughout the range (Agee 2002; Collins et al. 2015; Dunbar-Irwin and Safford 2016; North et al. 2009; Safford and Stevens 2017, page 15; Stephens 2004; Stephens et al. 2007; Stephens et al. 2015). Ridgetops and south-facing slopes would generally exhibit a higher proportion of trees as single individuals, a smaller proportion of trees as tree clusters, and a smaller number of trees per cluster. Drier portions of the landscape would also have more variation in the distance between tree crowns.

For a more complete list of variables and their influence on vegetation characteristics for yellow pine and mixed-conifer forests in the Sierra Nevada, refer to Safford and Stevens 2017, table 11, pages 178 and 179.

Habitat Suitability and Quality

Vegetation characteristics that influence the suitability and quality of CSO habitat are complex and vary strongly by latitude, elevation, vegetation type, site productivity, and topographic position. Important characteristics include, but are not limited to, the abundance and density of large/tall trees, the proportions and extent of moderate and high canopy cover, the amount of young forests with a hardwood component, the abundance and type of snags and downed woody material, the amount and distribution of prey habitat, and the heterogeneity of these characteristics within a given area.

Given limitations in data availability, habitat suitability is usually defined using the subset of these important characteristics that can be easily measured at broad scales. For example, the highest quality nesting and roosting habitat for the CSO, as defined using only average tree size and canopy cover, consists of areas with large/tall trees (more than 24 inches, but preferably more than 30 inches QMD[3]) and moderate to high canopy cover (more than 40 percent cover). Suitable nest/roost/forage habitat (as described using these same two metrics) also includes areas with medium-sized trees (11 to 24 inches QMD), and moderate-to-high canopy cover (table 2).

While multiple data sources exist to define habitat suitability and quality, conservation measures in this Strategy currently reference the California Wildlife Habitat Relationships (CWHR) system (Mayer and Laudenslayer 1988) (table 2). CWHR is currently the only dataset consistently available across the CSO range. However, CWHR stand size characteristic is based upon an average stand diameter; therefore, when forests have a mixture of tree sizes or diameters, it can be difficult to distinguish younger from older forests. Also, the CWHR categories are very broad, and the classification system does not reflect aspects of structure that are important to the CSO such as very large trees and snags (North et al. 2017a, North and Manley 2012).

Table 2. Suitable habitat for the CSO using the California Wildlife Habitat Relationships[2]

CWHR Classification	Tree Size QMD	CWHR Canopy Class	Canopy Cover	Vegetation Types
4D	11 to 24”	Dense cover	60 to 100 percent	DFR, MHC, MHW, MRI, PPN, RFR, SMC, WFR
4M	11 to 24”	Moderate cover	40 to 59 percent	
5D	more than 24”	Dense cover	60 to 100 percent	DFR, EPN, JPN, LPN, MHC, MHW, MRI, PPN, RFR, SMC, WFR
5M	more than 24”	Moderate cover	40 to 59 percent	
6		Multilayered canopy with dense cover		

[2] CWHR habitat types for CSO include Douglas fir (DFR), eastside pine (EPN), Jeffrey pine (JPN), lodgepole pine (LPN) montane hardwood-conifer (MHC), montane hardwood (MHW), montane riparian (MRI), ponderosa pine (PPN), red fir (RFR), Sierran mixed conifer (SMC), white fir (WFR).

The CWHR definitions of suitable habitat set forth above provide a rough metric for both nesting/roosting and foraging habitat. While these simplified guidelines provide easily applied metrics, they are both over inclusive and under inclusive in characterizing suitable habitat, and therefore, should not be rigidly applied without consideration of site-specific factors. For example, the definition of suitable nesting habitat may be over inclusive in some instances, such as where an even aged stand of 12-inch dbh trees with 70 percent canopy cover meets the CWHR definition of suitable nesting habitat, but such conditions would almost certainly not provide suitable nesting habitat due to the lack of large/tall trees; indeed, North et al. (2017a) found CSOs selected against such areas.

[3] CWHR large tree size class does not differentiate categories beyond more than 24 inches. Where other vegetation data are available, habitat quality can be further differentiated in the larger tree size classes. Habitat with QMD more than 30 inches is of higher quality than that with QMD between 24 and 30 inches (Jones et al. 2017, North et al. 2017a).

On the other hand, the CWHR classifications above are likely under inclusive of foraging habitat. CSOs forage on various species that live in early seral conditions and benefit from the presence of hardwoods. This suggests CSOs use some early seral stands for foraging, and a higher basal area of hardwoods improves foraging habitat quality. Numerous studies have recognized the importance of considering prey habitat in defining suitable owl habitat (see Roberts 2017 and references therein), the value of edge conditions for foraging (Eyes 2014, Eyes et al. 2017, Williams et al. 2011), and the importance of heterogeneity to provide a diversity of stand sizes and ages to meet both nesting and foraging needs (Atuo et al. 2018, Franklin et al. 2000, Roberts 2017, Tempel et al. 2014a, Ward et al. 1998, Zabel et al. 1995). In fact, successful CSO reproduction is more likely at diverse sites that include both north-facing slope (likely sustaining suitable nesting/roosting habitat and cooler microclimates) and younger forest with high basal area of hardwoods (likely important for prey species) (Hobart et al. 2019).

Therefore, while table 2 provides a useful starting point to determine whether a given area may be suitable habitat, land managers should apply the best available scientific information (including new vegetation datasets at higher resolution as they become available) to site-specific conditions to refine such determinations. Similarly, managers should apply the best available scientific information to site-specific conditions to determine whether a proposed management action would likely render currently suitable habitat unsuitable or vice versa.

Managers should take a similar approach in determining whether a proposed management action would change habitat quality for the CSO. Certain activities (for example, surveys) are recommended in section 9 when actions are likely to reduce habitat quality for the CSO. Not all management actions that impact habitat suitability characteristics (such as canopy cover or the abundance of medium-sized trees) should be considered a reduction in habitat quality since the quality of habitat in a given location involves a complex mix of numerous factors. For example, sites at lower elevation and lower latitudes may see an improvement in habitat quality with some reduction from high to moderate canopy cover and some promotion of hardwoods over other species, while similar actions at higher elevations, higher latitudes, and more northern aspects may result in a reduction in habitat quality. Minor reductions in canopy cover (for example, reductions that maintain habitat in the same CWHR class) would not be expected to decrease habitat quality nor would increasing habitat diversity outside the 10-acre nest stand through increased ICO (individual tree, clumps, openings) management. Conversely, significantly increasing the proportion of habitat within a PAC that is in the low-canopy-cover class (less than 40 percent canopy cover) is likely to reduce habitat quality.

Surveys

This Strategy recommends survey protocols evolve over time in response to the best available scientific information. Thus, surveys discussed in this Strategy are the most current protocols available at the time of survey. Further, in some instances, project- or area-specific deviations from, or amendments to, a standard protocol may be appropriate, when alternative approaches can provide high-quality survey information with greater efficiency. In other instances, various forms of monitoring may be sufficient for decision making, and no additional surveys may be necessary.

Section 9: Approaches and Recommended Conservation Measures

Approach 1. Conserve California Spotted Owl Habitat and Habitat Elements around Occupied CSO Sites

Approach 1 focuses on the immediate need for maintaining high-quality habitat, especially around occupied nest sites, while resilient habitat is developed across the landscape as described in approach 2. Approach 1 emphasizes managing owl habitat at the PAC and territory scales to ensure successful CSO reproduction. Ultimately, the goal is to move Sierra Nevada forests as a whole toward NRV where there would be an abundance of owl nesting, roosting, and foraging habitat distributed across the landscape and PACs would no longer be necessary. In the interim, however, PACs are an important component of a conservation strategy that considers both short- and long-term needs of the species.

To meet the Strategy goals, PAC management should continually improve the effectiveness and dynamic nature of the PAC network. To accomplish this, PAC boundaries should be modified if needed to better support known CSO occupancy and habitat use, to better align with long-term sustainability of suitable nesting and roosting habitat, or both. Further, PACs that are currently occupied, that are likely to contribute disproportionately to population growth and reproduction, or both should be maintained and improved. PACs should be retired or removed from the network when disturbance events change their conditions so significantly as to make their contribution to the population unlikely, if they have not been consistently occupied or reproductive in recent years, or both. Areas that were once but are no longer in active PACs should be managed to increase long-term suitable and sustainable habitat development in a dynamic landscape.

This approach aims to maintain high-quality habitat while protecting it from risk of loss from high-severity wildfire and other stressors. This requires balancing the retention of high-quality habitat with necessary treatments to increase resiliency, which may cause short-term decreases in habitat quality. To minimize near-term effects of resiliency treatments, such treatments should be implemented only when needed and should be designed to maintain the most important habitat components, such as areas of high canopy cover (more than 55 percent) in large/tall trees within PACs. Some PACs will include areas that may be unsustainable in the long term but have an acceptable near term risk, such as PACs with the highest likelihood of reproductive success.

This approach also includes measures to maintain and promote high-quality habitat at the territory scale. Territorial spotted owls, including pairs (with young), defend a geographic area, known as a territory or core area, used for nesting, roosting, and foraging, which is essential for CSO survival and reproduction. Desired conservation outcomes for territories are to maintain and increase high-quality nesting, roosting, and foraging habitat while increasing habitat heterogeneity and resilience.

The habitat characteristics described below are largely derived from CSO habitat use west of the Sierra Crest. CSO habitat selection and demographic parameters likely differ on the east side. Therefore, PACs and territories east of the Sierra Crest may have lower canopy cover, fewer canopy layers, smaller trees, or a combination of these things, depending on site conditions. They will likely need to deviate from the specific measures described below to best conserve CSO PACs and territories within the capability of the forests.

PACs

1. Designate activity centers and PACs.

A. Survey suitable CSO nesting and roosting habitat of unknown occupancy status[4] in advance of any management activities that would reduce CSO nesting and roosting habitat quality.

B. Designate owl activity centers for territorial owl pairs based on (1) the most recent documented nest site, (2) the most recently known roost site when a nest location remains unknown, or (3) a central point based on repeated daytime detections when neither nest nor roost locations are known.

C. Designate PACs surrounding each activity center to include 300 acres of the highest quality nesting and roosting habitat, in as compact an area as possible, comprised of (1) CWHR classes 6, 5D, 5M, 4D, and 4M (listed in descending order of priority); (2) at least two tree canopy layers; (3) dominant and codominant trees averaging more than 24 inches dbh; (4) more than 60 to 70 percent canopy cover; (5) large snags (at least 45 inches dbh); and (6) snag and down woody material levels that are higher than average.

D. Where possible, delineate PAC boundaries based on the best available information (for example, biophysical, climatic water deficit, Landscape Management Unit [LMU]) to include the most sustainable locations of high-quality nesting and roosting habitat, where such habitat can be resilient to natural disturbances and climate change.

2. Minimize PAC disturbance.

This Strategy recommends minimizing disturbance to breeding owls by using limited operating periods (LOPs) during the breeding season (March 1 to August 15) when necessary for specific activities described below. The use and scope of the LOPs will depend upon the magnitude, duration, and frequency of activities and should be discussed with a USFS interdisciplinary team. LOPs may be modified or waived under any of the following conditions: (1) when surveys indicate absence of nesting owls, (2) when activities are of small scale and short duration, or (3) when the benefit of management activities to habitat resilience outweighs the potential short-term risk to owls.

A. Apply a 0.25-mile (125-acre) buffer around an active nest during the breeding season that limits or prohibits mechanical harvest activities that may disturb breeding owls. This LOP does not apply to existing road and trail use and maintenance.

B. Avoid prescribed burning closer than 500 feet from active nests during the breeding season. This restriction may be waived in up to 10 percent of PACs per year in a national forest, where necessary to facilitate the benefits of using early season prescribed fire.

3. Modify individual PACs, the PAC network, or both based on biophysical conditions, disturbance events, or lack of occupancy.

[4] "Suitable CSO habitat of unknown occupancy status" is at least 300 acres of suitable habitat, in as compact an area as possible, within a territory sized area (800 or 1,000 acres; see Table 1) that falls completely outside known territories and has not been surveyed for more than 3 years

A. PAC modification

   1) Adjust PAC boundaries, as needed, based on the best available information (for example, biophysical, climatic water deficit, LMU) to include the most sustainable locations of high-quality nesting and roosting habitat, where such habitat can be resilient to natural disturbances and climate change.

   2) As CSO nesting or roosting habits change, adjust PAC boundaries as needed to include new nest sites or concentrated areas of roosting which do not fall within PAC boundaries.

   3) PAC boundaries should be modified when large-scale disturbance events make nesting and roosting habitat within a PAC unsuitable or when owl data indicates owl nesting has shifted to areas outside of a PAC. Assess habitat conditions within a 1.5-mile radius of an activity center to modify PACs according to PAC designation criteria described above (or to retire the PAC, according to the guidance set forth below).

B. PAC retirement based on disturbance

   1) When a territory associated with a PAC experiences more than 75 percent basal area mortality over more than 50 percent of the territory, conduct surveys one year post disturbance within the PAC. If neither nesting nor territorial activity by a pair of owls is documented, the PAC and associated territory may be retired. Retain and protect those areas in the territory with the highest potential to support future CSO breeding and nesting/roosting habitat

   2) When a PAC has experienced a large-scale disturbance (for example, wildfire, tree mortality from drought and insects) that substantially reduces suitable habitat, assess habitat conditions within a 1.5-mile radius of the activity center to determine if 300 acres of suitable nesting and roosting habitat remains that would satisfy the PAC designation criteria. If insufficient suitable habitat exists to remap the PAC, the PAC and associated territory may be retired. If the PAC can be remapped, refer to the prior subsection for PAC boundary modification.

C. PAC retirement based on lack of occupancy

   1) When a PAC has been surveyed repeatedly over time (at least two years of surveys within the last 12 years) with no observed breeding activity nor territorial behavior by an owl pair, monitor or survey the PAC for an additional three consecutive years. If no owl is detected, the PAC and associated territory may be retired. If an owl is detected but no breeding activity nor territorial behavior by an owl pair has been documented, the PAC and associated territory may be retired.

   2) When a PAC has unknown breeding activity and no history of protocol level surveys, monitor or survey for five consecutive years. If no owl is detected, the PAC and associated territory may be retired. If an owl is detected but no breeding activity nor territorial behavior by an owl pair has been documented, the PAC and associated territory may be retired.

D. Manage retired PACs applying the restoration and resiliency treatments for desired conservation outcomes in approach 2. For example, design treatments in retired PACS to retain available large/tall tree, high canopy cover habitat that is resilient to disturbance.

4. **Manage PACs for resiliency and sustainability while minimizing near-term effects of resiliency treatments.**

   A. Fire, hand treatments, mechanical treatments, or a combination of these things may be necessary in PACs to increase resiliency and sustainability. Prioritize treatments in PACs that are at highest risk of large-scale, high-severity wildfire or severe tree mortality from insects and drought. Design treatments to maintain and promote the highest quality nesting and roosting habitat available.

   B. In addition to prioritization by risk level, prioritize treatments in PACs based on the history of active nesting and pair territorial behavior where information is available. Treatments that may have negative near term effects should be minimized or avoided in PACs with the highest likely contribution to reproductive success.

      1) Prioritization for PAC treatment (listed from highest to lowest priority for treatment):

         - PACs presently unoccupied and historically occupied by territorial singles only
         - PACs presently unoccupied and historically occupied by pairs
         - PACs presently occupied by territorial singles
         - PACs presently occupied by pairs
         - PACs presently occupied by pairs and currently or historically reproductive

   C. When treating within PACs, design treatments to minimize impacts to reproductive owls and key owl habitat elements. Generally retain the highest quality habitat (CWHR 6, 5D, 5M), especially in areas with higher canopy cover (more than 55 percent) in large/tall trees.

   D. Design fuels treatments in PACs, by reducing surface and ladder fuels and minimizing impacts to overstory canopy, to manage for low- and moderate-intensity fires (flame lengths less than 4 feet and less than 6 feet, respectively), which will provide conditions for continued nesting and roosting.

   E. When practicable, use fire as the primary tool for achieving restoration goals within PACs.

   F. Avoid mechanical treatments within 10 acres surrounding a nest tree or nest structure.

   G. Reduction in habitat quality is acceptable in up to one third (100 acres) of a PAC where necessary to increase long-term resilience, provided (1) the QMD is increased for the PAC as a whole; (2) a minimum of 50 percent canopy cover is maintained, averaged at the PAC scale; (3) habitat quality will increase post treatment; and (4) habitat quality is maintained in the highest quality nesting and roosting habitat (for example, CWHR 6, 5D, 5M).

Territory/Watershed Scale

1. **Designate territories.**

   A. Territory size is approximately 800 acres in the southern Sierra Nevada (the Sierra, Sequoia, and Inyo National Forests) and 1,000 acres in the rest of the Sierra Nevada. The territory includes the 300-acre PAC.

   B. Generally, map territories as a circular core around an activity center. However, territory boundaries may be adjusted to be noncircular, as needed, to include the most sustainable areas of high-quality habitat and exclude areas less likely to support suitable habitat.

2. **Promote sustainable and resilient owl territories at either the territory scale or, in areas with multiple territories, at the watershed scale.**

   A. **Territory**. Desired conservation outcomes for an occupied territory are to maintain and promote 40 to 60 percent of a territory in mature tree size classes with moderate and high canopy cover for nesting, roosting and foraging. This corresponds to roughly the following CWHR size/density classes in descending order of priority: 6, 5D, 5M, 4D, and 4M. Those territories in more mesic conditions and at higher elevations within the watershed should contain relatively more of this habitat than those in drier conditions and at lower elevations. The remainder of the territory should represent a diversity of many different structure and canopy cover classes.

      1) When occupied territories do not meet the desired conditions described above, retain the existing large tree moderate/high canopy cover habitat (for example, CWHR 6, 5D, 5M) wherever it exists throughout the territory.

   B. **Watershed.** Desired conservation outcomes for multiple territories comprising more than 75 percent of a watershed (typically a hydrologic unit code [HUC] 8 unit and more than 10,000 acres in size) is to maintain 30 to 50 percent of the watershed in mature tree habitat at moderate and high canopy cover (for example, CWHR 6, 5D, 5M, 4D, and 4M).

   C. Manage territories to foster development of high-quality habitat and habitat connectivity

      1) Within territories, retain patches of large/tall trees (more than 48 meters [approximately 160 feet]) with high canopy cover (more than 70 percent), both inside and outside of PACs, for developing future nesting sites.

      2) Promote habitat connectivity at the watershed scale by retaining connected areas of moderate and high canopy cover in large/tall trees within territories.

      3) Increase resiliency for territories at the watershed scale by reducing tree density of smaller trees that are prohibiting growth of larger trees. Thinning treatments within territories should be designed to minimize the loss of and to recruit large and very large trees and snags (at least 24 inches and at least 36 inches dbh, respectively).

Approach 2. Restoration of Resilient Forest Conditions Guided by NRV

A central tenet of this Strategy is to encourage active management at a rapid pace and scale to promote resilient CSO habitat throughout the landscape. NRV conditions provide a useful reference for restoring CSO habitat to be resilient and sustainable across the landscape. Active management can involve a mix of mechanical treatments and prescribed or managed fire to achieve desired conservation outcomes.

Restoration-oriented active management will reduce threats to owl habitat from large-scale disturbances, as well as increase benefits of habitat diversity. Effective use of mechanical thinning, fire, or both to reduce stand densities will increase the resilience of forests to fire, drought, and disturbances incited by drought (Fettig et al. 2019, Kolb et al. 2016, North et al. 2015a, North et al. 2015b).

Restoration treatments that reduce stand density can also facilitate regeneration (York et al. 2004, Zald et al. 2008), accelerate the development of the large and tall trees favored by spotted owls (Das et al. 2008, Latham and Tappeiner 2002, McDowell et al. 2003, Ritchie et al. 2008, Skov et al. 2004), and reduce competitive stress around existing large trees (Fettig et al 2007, McDowell and Allen 2015, Safford and Stevens 2017, Young et al. 2017). Restoration of heterogeneous patterns in distribution, tree density, and tree species composition that mimic historic conditions may contribute to a forest that is resilient to mass disturbances (Fry et al. 2014, Show and Kotok 1924, Stephens et al. 2008), especially catastrophic wildfire, while increasing habitat diversity for the CSO and their prey.

Since fire was the dominant disturbance agent that shaped Sierra Nevada forests under NRV, reintroduction of fire as an ecosystem process is an important element of this Strategy. However, given the reintroduction of fire is not presently practical or safe in some parts of the Sierra Nevada, forest thinning may be used as a fire surrogate (albeit an imperfect one) to help move current forests toward NRV. To mimic the effects of a natural fire regime, managers would need to burn, mechanically treat, or both 184,000 to 488,000 acres annually on National Forest System lands in the Sierra Nevada (North et al. 2012). Given the backlog of nearly 3 million acres of fire-suppressed land (North et al. 2012), active management is needed at a significant pace and scale. Treating more than 20 percent of the landscape with strategic treatments can reduce modeled fire size and behavior (Collins and Skinner 2014), but effectively influencing ecosystem function, especially where treatment patterns are limited by management constraints, requires restoring, treating, or both more than 40 percent of the area at the landscape scale (Lydersen et al. 2017). At a mid-scale (1,000s to 10,000s of acres), roughly 25 to 60 percent of the area may need to be treated to influence fire severity (Lydersen et al. 2017), and at a patch/stand scale, more treatment may be necessary to influence fire severity (50 to 75 percent at the scale of 500 acres; Lydersen et al. 2017). Even more treatment for restoration may be required under future climate regimes (Westerling et al. 2015).

As guided by information on NRV and climate change, approach 2 encourages forest managers to increase the resiliency of owl habitat to fire and other disturbances. Generally, this will require active management to (1) increase within- and between-stand heterogeneity; (2) reduce stand densities; (3) increase the large tree component on the landscape; (4) increase the relative abundance of fire-tolerant and shade-intolerant tree species; (5) reduce ground fuels; (6) increase management by fire, both prescribed and managed wildfire; and (7) actively restore habitat after disturbances that do not align with NRV.

1. **Increase forest heterogeneity.**
    - A. Manage for structural diversity at multiple scales consistent with site characteristics and variable influences of natural disturbances.
        - 1) At the landscape scale, manage towards a mix of seral stages and canopy conditions consistent with NRV. This will generally entail increasing the amount of open canopy habitat in all seral stages and the amount of late seral stand conditions (open or closed canopy) to get a patchy distribution of diverse stand types. Seral stage desired conditions can be inferred by comparing current conditions with the level of departure from historic conditions (for example, Safford and Stevens 2017, pages 177 through 181; table 11, pages 178 and 179).

2) At the stand/patch scales, manage for within-stand and multi-stand diversity. Manage for a pattern of individual trees, clumps of trees, and openings (ICOs) containing various sizes of clumped trees and openings. These patterns range in size, configuration, and frequency based on NRV (Safford and Stevens 2017, table 8, page 140).

B. Manage the understory of mid- and late-seral areas for a patchy distribution of shrubs, forbs, tree regeneration patches, and bare ground to increase diversity, reduce fuels continuity, and provide habitat for owl prey species.

2. Reduce tree densities.

A. Reduce tree densities at multiple scales, commensurate with NRV for the area being managed, to conditions that are sustainable under a changing climate, that are less susceptible to disturbance, and that will maintain suitable owl habitat.

1) Retain a diversity of size and age classes consistent with NRV. Retain sufficient smaller trees to provide habitat diversity and recruitment of future large trees.

B. Remove trees in overrepresented size classes and retain the largest trees in the stand. This will provide both space and resources for remaining trees to grow larger and more resilient.

1) Where long-term fire exclusion has resulted in stand densities outside NRV, reduce densities in small- to medium-size classes across seral stages and canopy-cover classes, while retaining representation of at least three age/size classes where they exist. The lowest tree densities would be in open-canopy, late-seral stands on low-productivity, dry sites. The highest densities would be in closed-canopy, early- and mid-seral stands on high-productivity, wetter sites.

C. Reduce tree density while retaining large and structurally-complex trees and snags. Recruiting more large trees and increasing their ability to resist future drought events and increasing temperatures will require reducing competition, particularly on drier sites.

3. Retain large, old trees and snags.

A. Maintain and promote large, old, and structurally complex trees and snags to provide quality owl nesting and roosting habitat. For desired conditions of old and structurally complex trees and snags in yellow pine and mixed-conifer forests, refer to Safford and Stevens 2017, pages 141 through 145 and table 11, pages 178 and 179.

B. Promote and maintain large, shade-intolerant trees such as yellow pine and black oak by considering the ecological tolerances of common tree species (Safford and Stevens 2017, table 2, page 10).

C. Maintain large/tall trees where biophysical conditions are likely to be sustainable to support both high canopy cover and large/tall trees in the future.

D. Due to the current deficit of very large trees as indicated by the departure from NRV (Safford and Stevens 2017, page 97; table 11, page179), trees more than 30 inches dbh should not be removed from occupied CSO territories. Outside occupied CSO territories, trees of 30 to 40 inches dbh should only be removed in very limited instances for restoration and resilience purposes, as guided by NRV. As the abundance and distribution of large and very large trees begins to align with NRV, this recommendation may no longer be necessary. Circumstances for removal of 30- to 40-inch dbh trees outside occupied CSO territories could include the following:

1) Removal of select shade-tolerant trees to promote existing shade-intolerant pine species in the same area of comparable size, such as ponderosa pine or sugar pine, or shade-intolerant broadleaved species, such as black oak or aspen.

2) Removal of select shade-intolerant trees to promote the establishment, growth, and development of stands with multiple size and age classes, and create small gaps in historically pine dominated stands.

3) Removal of trees surrounding rust-resistant white pine to improve the growth and vigor of these trees and maintain this valuable genetic resource on the landscape.

4) Removal of select conifers to restore aspen, oaks, or meadows.

5) Thinning of trees in homogeneous plantations where large diameter trees are at risk due to competition.

4. Restore the proportion and distribution of tree species on the landscape consistent with NRV and potential vegetation type.

A. Increase the abundance and distribution of fire-resilient and resistant species (for example, ponderosa pine, sugar pine, Jeffrey pine, and black oak) and decrease the abundance of shade-tolerant species (for example, white fir, incense cedar, Douglas fir).

1) Promote species diversity as guided by NRV.

2) Remove smaller trees and fire-sensitive species that would not have survived under a natural fire regime.

5. Restore the amount and distribution of duff, litter, and woody debris.

A. Manage stands for relatively low levels of surface fuels, relatively low but variable levels of coarse woody debris, and variable densities of logs across the landscape.

1) Manage surface fuels, fine fuels, and coarse woody debris (CWD), to correspond with the distribution and volume of duff, litter, and woody debris consistent with NRV. Refer to Safford and Stevens 2017 (pages 141 through158 and pages 177 through 189) for guidance on appropriate NRV conditions.

2) At the stand scale, manage for patches of CWD and thick litter layers interspersed with areas of shrubs and open areas with only ground vegetation, such as forbs and grasses. Avoid continuity of heavy surface fuels.

3) Preferentially retain logs in the largest size classes to reach NRV goals.

B. When possible, use prescribed fire or managed fire to achieve NRV conditions for duff, litter, and woody debris. When using fire alone is not practical to achieve NRV conditions, use manual or mechanical means in combination with fire.

6. **Restore natural disturbance regimes.**
   A. Increase large-scale application of managed and prescribe fire to maintain dynamic ecosystem structure and function.
   B. Base fire restoration efforts (prescribed or managed wildfire) on departures from NRV, as indicated by planning tools like the Fire Return Interval Departure (FRID) database. Areas with the highest departure from NRV (FRID condition classes 2 and 3), could be prioritized for wildfire reintroduction, assuming topography, weather, and fire risk patterns are conducive to achieving this objective.
   C. Manage prescribed fires and natural ignitions at multiple scales for a range of fire severity effects.
      1) To the extent feasible, manage fire at the landscape scale to create a mosaic of patches burned at low and moderate severities interspersed with large, unburned patches and small, high-severity burned patches. Generally, proportions of fire effects desired to mimic NRV are approximately unburned (10 to 30 percent), low severity (30 to 60 percent), moderate severity (15 to 35 percent), and high severity (1 to 10 percent).
      2) Design fire treatments in occupied owl territories with high-severity patch sizes generally less than 10 acres (potentially up to 100 acres) to minimize adverse impacts to occupied habitat.
7. **Manage highly disturbed areas for NRV-based restoration and conservation benefits.**
   A. When disturbances like fire and insect-outbreaks move landscapes away from NRV conditions, evaluate post-disturbance conditions across multiple scales (substand to landscape scale) to determine what management activities (such as reforestation or fuels reduction) may be necessary to achieve NRV conditions and associated conservation outcomes.
   B. When managing highly disturbed landscapes, strive to retain and protect the best available patches of owl nesting, roosting, and foraging habitat.
   C. When managing burned areas, consider retaining severely burned stands in areas more likely to have experienced severe fire effects under NRV, such as upper portions of south-facing slopes.
   D. When managing beetle-killed areas, retain some high-severity patches of beetle-killed trees to create edge habitats for foraging owls. Patch sizes should generally range between 0.25 to 10 acres and comprise less than 15 percent across the landscape (Fettig 2012), preferably in small clumps of 2 to 4 trees (Lyderson et al. 2013).

Approach 3. Minimize Non-Habitat Threats (Barred Owls, Disease, and Rodenticides)

The USFS is a member of the California Barred Owl Science Team (BOST), which informs development and implementation of research studies and regular interagency communication on barred owls. While barred owl numbers are likely still relatively low in the Sierra, recent increases have occurred (Wood et al. unpublished data), and it is anticipated increases will continue over time.

Given the current observed impacts of barred owls on the NSO, an interagency barred owl research and monitoring program for the CSO is being implemented. A barred owl research/monitoring program in the Sierra Nevada will further scientific knowledge on barred owls and their impacts on CSO.

Rodenticides are another emerging threat to the CSO, though no information is available at this time to evaluate the magnitude and consequences of this threat (Gutiérrez et al. 2017). High exposure rates were recently recorded in barred owls and NSOs (Gabriel et al. 2018, Gutiérrez et al. 2017, Thompson et al. 2017), and it is likely CSOs also have high exposure rates. More research is needed to assess exposure rates of CSOs, effects of exposure, and potential mitigation measures. Disease is not likely a current significant threat to CSO. However, little information exists on disease prevalence in CSO populations, and no information exists regarding the effects of disease on individual fitness or population viability, including West Nile virus, which has not significantly affected CSO populations (Gutiérrez et al. 2017).

1. **Implement monitoring and control studies of barred owls in the Sierra Nevada at the ecoregion scale.**
   A. Desired conservation outcomes of a barred owl removal study are to understand the impacts barred owls have on the CSO and to develop an effective management approach of barred owls in the Sierra Nevada. The USFS is currently working with USFWS, California Department of Fish and Wildlife (CDFW), the University of Wisconsin, and the BOST to implement a barred owl removal study in the CSO range.
2. **Use results from barred owl studies to design a barred owl management plan.**
   A. The USFS process for developing a barred owl management plan may include:
      - developing an outreach and communication program to foster public support and engagement in barred owl removal efforts
      - prioritizing survey efforts based on the likely natural progression of barred owls moving into the Sierra (north to south)
      - conducting surveys to determine barred owl locations
      - obtaining required permits for barred owl removal
      - monitoring effectiveness at both territory and ecoregional scales following removals
      - collaborating with landowners for information exchange on barred owl detections and removal
      - developing an adaptive management plan based on new information
3. **Increase understanding of the effects of disease and contaminants on California spotted owl fitness and seek to minimize any adverse effects.**
   A. Assess rates of rodenticide exposure as part of barred owl studies. Use the information from these studies to evaluate conservation measures to address the threat of rodenticides.
   B. Take an adaptive management approach if disease becomes a threat to CSO persistence.

Approach 4. Foster Climate Adaptation of California Spotted Owls and Their Habitat

For the CSO, lower-elevation sites (less than 4,500 feet) with warmer microclimates and more open canopy cover may be important near-term (the next 40 years) refugia, as lower-elevation owls may be more resilient to climatic warming (Jones et al. 2016a). Thus, increasing resilience and heterogeneity at lower-elevation sites is a key near-term climate adaptation strategy. In the longer term (end of the century and beyond), cooler, moister forest types at higher elevations with higher canopy cover are more likely to become refugia for the owls (Jones et al. 2016a, North et al. 2017a). Increasing presence and resilience of large/tall tree, closed-canopy forests at higher elevations (more than 4,500 feet) is an important aspect of developing future refugia for the species. Further, maintaining connectivity between lower-elevation, mid-century refugia and higher-elevation, late-century refugia will become important to aid in species migration as refugial patterns shift upslope.

1. During reforestation efforts, proactively augment forest resilience through assisted tree gene and species migration for the purpose of developing future CSO habitat resilient under potential future climate conditions.
2. Manage cooler, moister forest types at higher elevations to promote sustainable high-quality CSO habitat as climate refugia.

Approach 5. Develop Collaborative Efforts to Implement CSO Conservation

Landscape restoration will require an all-hands approach to increase the pace and scale of active management to maintain sustainable CSO populations and increase habitat resiliency to large-scale, high-severity wildfire and other disturbances. The USFS currently participates in a variety of partnerships supporting CSO conservation.

1. Develop additional collaborations, and expand existing collaborations, to implement CSO conservation.

Section 10. Monitoring and Adaptive Management

Population and Habitat Monitoring

Monitoring is critical to increase understanding of rangewide and population-specific changes in spotted owl demographics (U.S. Fish and Wildlife Service 2017). While the existing long-term demography studies have provided a wealth of information on CSOs, important knowledge gaps remain. In particular, CSO distribution and population dynamics outside of the demographic study areas, as well as viable/sustainable population sizes and responses to regional-scale stressors, remain largely unknown (U.S. Fish and Wildlife Service 2017). Further, trends in key CSO habitat, particularly in relation to biophysical conditions and management regimes, remain relatively unclear. The development and implementation of rangewide monitoring programs will help fill these knowledge gaps, answer important questions, and provide the basis for improving conservation efforts. Coordination of a monitoring program that reaches across agencies, landownership, habitat types, and different management regimes will be critical to informing an adaptive management context in the future.

Information sharing and research and monitoring partnerships are already underway between the USFS and other agencies (like the National Park Service and U.S. Fish and Wildlife Service), research institutions (like universities and the Pacific Southwest Research Station), and landowners with significant proportions of the CSO habitat. These partnerships and collaborations should be continued and expanded in the future to carry out effective monitoring programs.

Questions and metrics of success

Listed below are key questions and metrics of success to guide a monitoring program and associated adaptive management.

1. **Is the population and distribution of California spotted owls likely declining, increasing, or stable?** What is the current occupancy across the range, particularly as related to Protected Activity Centers and modeled suitable habitat? How is occupancy changing over time and space?

   Metrics of success

   - CSO occupancy is dynamic but not declining at the rangewide scale over a 10-year period
   - CSO occupancy is constant or increasing in more sustainable locations (for example, moister locations, drainages)

2. **How is California spotted owl habitat changing over time?** Is the number of large trees on the landscape increasing and is the distribution of large trees changing? Is the distribution of large-tree, high canopy cover habitat increasing in alignment with biophysical conditions likely to support that habitat? How are the number and locations of PACs on the landscape changing over time?

   Metrics of success

   - Number of large trees increasing at the landscape scale
   - Average canopy cover is reduced at the landscape scale to align with NRV, while canopy cover at the patch/stand scale is maintained in areas dominated by large trees
   - Area of occupied CSO territories in large tree, high canopy cover habitat is increasing
   - Canopy cover and tree density alignment with biophysical conditions is increasing

3. **How are threats to the California spotted owl changing over time?** Are barred owl populations increasing in size, distribution, or both? Is the rate of change in barred owl populations constant, increasing, or decreasing? How are fire size, fire severity, and overall area burned trending over time? If the distribution of owls is changing over time, is there a relationship to changes in habitat, disturbance, mortality factors like rodenticides, or management activities?

   Metrics of success

   - Barred owl populations are decreasing in both size and distribution
   - Risk of high-severity fire in occupied CSO territories is decreasing

- Trends in fire size and severity patterns are reversed so that patterns are on a trend towards NRV
- Risk of high levels of insect/drought-related mortality in occupied CSO territories is decreasing

Objectives

1. Assess the current distribution of California spotted owls in the Sierra Nevada
2. Monitor changes in California spotted owl distribution and multi-state occupancy rates over time
3. Assess changes in the amount and distribution of key habitat, including large/tall trees and large/tall tree, high canopy cover habitat
4. Assess trends in stressors over time and effects of disturbance and restoration on California spotted owl
5. Prioritize restoration for PACs and territories by risk level
6. Monitor effects of barred owls (see barred owl monitoring section below)

Methods and information sources

Population

CSO population monitoring may be achieved using multiple methods and information sources. The long-term CSO demography studies are not representative samples of the population and thus limit our ability to draw inferences about population trends and dynamics beyond their boundaries. Nonetheless, they have provided invaluable insights into demographic rates in a subsample of the population (Wood et al. 2019). Rangewide, multi-state occupancy monitoring (which provides information on occupied versus not occupied and also whether sites are occupied by a pair or single) can be conducted using autonomous, acoustic recording units (Wood et al. 2019). Acoustic recording units are already being used to monitor NSOs throughout their range and have recently been deployed in the northern Sierra Nevada to monitor CSOs (Wood et al. 2019).

Acoustic recording units may be used to passively record calls of spotted owls, barred owls, and other species. An acoustic recording unit array arranged in a sampling design matrix across the landscape would provide the data necessary to assess changes in the abundance and distribution of CSOs (and barred owls). Deployment of a network of acoustic recording units randomly within each of two different strata—protected activity centers and suitable habitat outside protected activity centers—may provide an image of overall occupancy and trends. A population sampling scheme, when combined with habitat monitoring metrics (see section below), will provide a framework for understanding how environmental change, forest management and restoration, and changes in barred owl populations influence CSO distribution and abundance.

Given potential weaknesses in occupancy estimation of CSOs (Berigan et al. 2018), acoustic monitoring methods will need to limit detection of the same individual at multiple sampling sites. This may be accomplished through appropriate distribution of sampling over both time and space, as well as developing methods to detect sex, individual identity, or both (Wood et al. 2019). Such methods are currently being explored by research partners.

Survey protocols may also be revised to incorporate acoustic-recording–unit-based surveys or other new technology following pilot study results.

Habitat and Management

Habitat will be monitored with mapping products that would allow frequent updates and discernment of key habitat characteristics for the CSO. Examples of current products include GNN (Ohmann and Gregory 2002) and FastEMap (Huang et al. 2017), though habitat mapping resources are quickly evolving. Habitat monitoring should combine information from vegetation plots, remote sensing, and management activity databases to include the following metrics: status and trend in canopy cover and large/tall trees, status and trend of CSO suitable habitat, and effects of disturbance and management on CSO habitat suitability. The Monitoring Trends in Burn Severity database, in combination with the Ecosystem Disturbance and Recovery Tracker (eDaRT) or other remote sensing tools, may be used to monitor fire trends and trends in other disturbances over time. Finally, the USFS Natural Resource Information System (NRIS) can be used to monitor trends in number and distribution of PACs over time.

Monitoring Other Threats

Barred Owl

The joint barred and CSO surveys (see above) will indicate barred owl distribution, and the barred owl removal study will also indicate which barred owls remain in, or recolonize, areas they occupied during removals. Surveys will also indicate whether CSOs returned after barred owls were removed. Multi-species occupancy models may provide a rigorous statistical approach for estimating joint occupancy and understanding how barred owls limit the distribution of CSOs. As information from initial barred owl studies develops, inventory surveys and removal strategies could be developed and refined as part of an adaptive management program.

Rodenticides

Information is needed to identify rodenticide exposure rates in CSOs and to understand potential trends in these exposure rates (U.S. Fish and Wildlife Service 2017). Monitoring of exposure rates, as well as working with law enforcement partners to monitor the amount of rodenticides on the landscape, will both be important for long-term CSO conservation (U.S. Fish and Wildlife Service 2017). As part of the barred owl removal studies, rates of rodenticide exposure will be assessed. Information from these studies will be used to evaluate conservation measures to address the threat of rodenticides.

Tree Mortality

Monitoring the CSO response to intensive habitat modification caused by tree mortality will be critical to informing conservation (U.S. Fish and Wildlife Service 2017). In addition, monitoring CSO response to management actions that respond to current mortality and prevent future mortality represents an important component of adaptive management for the CSO in a changing climate.

Additional Monitoring and Research Questions of Interest

Many additional questions of interest exist. For example, questions about CSO disease prevalence, parasite loads, genetics, prey population dynamics, effects of climate change on habitat and distribution, etc. See additional research gaps and questions in the conservation assessment (Gutiérrez et al. 2017). Establishment of a CSO working group could help direct research partners and funds towards questions of interest as they arise.

Adaptive Management

Conservation measures outlined in this Strategy should be modified and updated as information and conditions change through time. A well-maintained feedback loop between science and implementation is a key component to the success of this Strategy, and will require, at a minimum, novel and perhaps experimental management design, taking advantage of actions across different land ownership and management objectives; post-implementation monitoring of populations and habitats following novel or model management at large scales; and clear and timely communication across organizations and disciplines throughout the process. Monitoring of habitat, population, and management outcomes across different habitat types and management regimes (as described above) should be used to inform an adaptive management context. This Strategy should be revisited and revised as the science and data continue to rapidly evolve.

Adaptive Management Triggers

Below is a list of several triggers that would likely warrant a change in management. Adaptive management may also be appropriate in other instances not specifically listed here (such as the release of significant new scientific information or the development of new land management experience).

1. CSO occupancy declines significantly over space or time
2. The number of CSO territories occupied by singles versus pairs increases significantly
3. The risk of high-intensity fire increases significantly in occupied CSO territories
4. Extensive tree mortality within occupied CSO territories continues and increases in the northern and central Sierra Nevada
5. The number of large trees at the landscape scale declines; the amount of habitat in small/medium tree, high canopy cover increases significantly; or both
6. The area and proportion of fire burned at high severity continues to increase in occupied CSO territories

Adaptive Management Process

When one or more of the adaptive management triggers above are reached, significant new science or management experience has developed, or both, this Strategy should be revisited to determine whether changes need to be made. Once a trigger is reached, agency staff and scientists (from within or outside federal agencies) should be brought together to assess the new information. Once the assessment is complete, the group should advise the USFS whether changes to the Strategy are warranted, and, if so, which aspects may require revision. Once recommendations have been made, the USFS will make necessary revisions to the Strategy and related implementing documentation. Given the potential lag time between new information and formal modification of this Strategy, it may be appropriate for land managers to deviate from particular management recommendations in this iteration of the Strategy to best achieve CSO conservation outcomes.

Glossary

Active restoration: prescribed burning and mechanical treatments, hand treatments, or both implemented to restore vegetation pattern, structure, composition, and processes to the natural range of variation.

Activity Center: owl nest or roost.

Adaptive management: a management approach that involves exploring alternative ways to meet management objectives, predicting the outcomes of alternatives based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn about the impacts of management actions, and then using the results to update knowledge and adjust management actions.

Basal area: average amount of an area (usually an acre) occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height. It is expressed as per unit of land area (typically square feet per acre).

Canopy closure: the percentage of the sky obscured by vegetation when viewed from a single point.

Canopy cover: the percentage of forest floor covered by the vertical projection of the tree crowns.

Climatic water deficit: a measure of the difference between potential and actual evapotranspiration. It is an indirect measure of how dry a site is.

Coarse woody debris: dead wood including downed, dead tree and shrub boles; large limbs; and other woody pieces that are severed from their original source of growth or are leaning more than 45 degrees from vertical.

Connectivity: the ecological conditions that exist at several spatial and temporal scales to provide landscape linkages to allow exchange of flow, sediments, and nutrients; daily and seasonal movements of animals within home ranges; dispersal and genetic interchange between populations; and long distance range shifts of species, such as in response to climate change.

Core area: non-overlapping defended geographic areas in which a pair of territorial owls concentrates nesting, roosting, and foraging activities.

Crown fire: a fire that spreads from treetop to treetop, remaining in the tree crowns.

Even-aged management: management that results in stands of trees composed of a single age class; for example, clearcutting.

Fine fuel: 1-hour to 100-hour fuels (excludes 1,000-hour fuels or coarse woody debris).

Fire return interval departure: a quantification of the difference between current and pre-European-settlement fire frequencies.

Fire return interval: the average number of years between two successive fires.

Fire severity: degree of vegetation mortality. High severity (or severely burned) is more than 75 percent basal area mortality; moderate severity is 25 to 75 percent basal area mortality; low severity is less than 25 percent basal area mortality.

Foraging habitat: habitat that supports spotted owl prey species, especially key prey species like woodrat or flying squirrel.

Forest seral-stage: the developmental phase of a forest stand with characteristic structure and plant species composition.

Frequent-fire forests: forests that burned more frequently in the past. The frequent fire regimes typically result in primarily low- and moderate-severity burned areas with smaller proportions of high-severity patches.

Hand treatments: using chainsaws to achieve desired structure, composition, or pattern

Habitat elements: components of the ecosystem spotted owls use as habitat. Key habitat elements are those ecosystem components, like large/tall trees, that are preferentially selected for by spotted owls and are highly influential in occupancy, demographic rates, or both.

High severity fire: fire that has resulted in greater than 75 percent basal area mortality.

Historic range: range of spotted owls prior to European settlement.

Home range: the area used by an individual to meet its life-history requirements. Typically includes all nesting, roosting, foraging, and territorial activities.

ICO Management: Management at the stand/patch scale that increases heterogeneity/diversity by promoting a range of tree configurations, including individual trees (lone single trees), trees in clumps (roughly 2 to 10 trees together), and gaps (small areas empty of trees).

Ladder fuel: live or dead vegetation that allows a fire to climb up from the forest floor into the tree canopy.

Landscape Management Unit (LMU): a LMU system classifies a landscape into smaller, homogeneous units (LMUs) by characterizing land based on its physical characteristics, biological characteristics, cultural characteristics, or a combination of these characteristics. In the Sierra Nevada, a LMU tool was developed to parse a landscape into basic topographic categories, and two versions are available. The first version divides an area into nine LMUs resulting from three slope positions (canyon bottom/drainage, midslope, ridge) and three slope aspects (southwest, northeast, and neutral) following earlier published work. A second version divides an area into six LMUs (ridge, canyon bottom/drainage, southwest mid-slope less than 30 percent, southwest midslope more than 30 percent, northeast mid-slope less than 30 percent, and northeast mid-slope more than 30 percent) following feedback from forest managers.

Landscape Scale: the landscape scale, roughly 10,000 to 100,000 acres in size, generally corresponds to the scale of a few to tens of spotted owl home ranges. The landscape is a historically heterogeneous area that would support many spotted owl territories and a variety of habitat conditions, largely influenced by climatic and topographic traits.

Large/tall tree: a tree that is generally greater than 48 meters (approximately 160 feet) tall, greater than 36 inches in dbh, or both. Large/tall tree habitat is dominated by the characteristics of large/tall trees, such that quadratic mean diameter (QMD) at the patch/stand scale is generally more than 30 inches.

Limited operating periods: restricted timeframe when specified activities (for example, mechanical harvest) may not occur to prevent or minimize disturbance to California spotted owls during the breeding, nesting, and fledgling periods.

Low-severity fire: fire that results in less than 25 percent basal area mortality.

Managed wildfire: a strategic choice to use unplanned wildfire starts to achieve resource management objectives and ecological purposes under specific environmental conditions.

Mechanical treatment: machine-based fuels reduction and tree harvest (for example, use of ground-based heavy equipment such as feller-bunchers and skidders or aerial-based systems such as cable yarding systems or helicopter). Excludes hand thinning with chainsaws.

Mega fire: a very large wildfire, typically one covering more than 100,000 acres.

Mid-scale: the mid-scale, approximately 1,000 to 10,000 acres in size, roughly corresponds to the scale of one to multiple spotted owl territories or home range. Forest-dominated landscapes comprise many vegetation patches or stands. These patches are distinct from one another in terms of vegetation type (for example, tree or shrub dominated), forest structure and species composition, disturbance history, or a combination of those things. The mid-scale connects the stand or patch scale (10 to 1,000 acres) to the landscape scale (10,000 to 100,000 acres) and is highly relevant to disturbance spread patterns, distribution and habitat use patterns of species with large home ranges, and forest management planning. CSO will use many patches within a given mid-scale area.

Moderate-severity fire: fire that results in 25 to 75 percent basal area mortality.

Mortality factor: cause (either direct or indirect) of death of an individual or multiple owls.

Natural disturbance regime: disturbance regime under which an ecosystem or species evolved prior to recent (post-European settlement) management interventions, such as fire suppression.

Natural range of variation (NRV): the variation of ecological characteristics and processes over scales of time and space appropriate for a given management application. The NRV concept focuses on a subset of past ecological knowledge developed for use by resource managers incorporating a past perspective into management and conservation decisions. The pre-European-influenced reference period is considered to include the full range of variation produced by dominant natural disturbance regimes such as fire and flooding and should also include short-term variation and cycles in climate. NRV is a tool for assessing ecological integrity and does not necessarily constitute a management target or desired condition. NRV can help identify key structural, functional, compositional, and connectivity characteristics for which plan components may be important for either maintenance or restoration of such ecological conditions.

Occupancy: stable (not transient) presence of at least one individual in a given area.

Patch: a definite shape and spatial configuration, and can be described compositionally by internal variables such as number of trees, number of tree species, age of trees, height of trees, or other similar measurements.

Population stability: probability of a population returning quickly to a previous state or not going extinct.

Productivity: forest site productivity is the production that can be realized at a certain site with a given genotype and a specified management regime. Spotted owl productivity is the owl reproductive rate.

Protected activity center (PAC): 300 acres of the highest-quality nesting and roosting habitat, in as compact an area as possible, comprised of (1) CWHR classes 6, 5D, 5M, 4D, and 4M (listed in descending order of priority); (2) more than two tree canopy layers; (3) dominant and codominant trees averaging more than 24 inches dbh; (4) more than 60 to 70 percent canopy cover; (5) large snags (more than 45 inches dbh), and (6) snag and down woody material levels higher than average.

PAC network: all of the currently occupied PACs. Location and survey history information for each PAC within the PAC network is maintained in a database. Retired PAC information is also maintained in the database, and this information includes the date retired. Retired PACs are no longer part of the PAC network, but make up part of the history of PAC management.

Quadratic mean diameter (QMD): a measure of central tendency or measure of average tree diameter in a stand, which is considered more appropriate than arithmetic mean for characterizing the group of trees which have been measured.

Resilience: the ability of a population or ecosystem to recover quickly, maintain function after a disturbance, or both.

Snag: a standing dead or dying tree, often missing a top or most of the smaller branches.

Sparred owl: a hybrid of a barred owl and spotted owl.

Stand: a contiguous group of trees sufficiently uniform in age class distribution, composition, and structure growing on a site of sufficiently uniform quality to be a distinguishable unit (such as mixed, pure, even-aged, and uneven-aged stands).

Stand/patch scale: the stand (or patch) scale, tens to 1,000 acres in size, roughly corresponds to the scale of a spotted owl nest site, up to a spotted owl protected activity center or territory.

Stand density index (SDI): a measure of the stocking of a stand of trees based on the number of trees per unit area and diameter at breast height of the tree of average basal area.

Stem density: the number of trees over a given area.

Suitable habitat: an area in which a species can or does occur. For this Strategy, we use the CWHR CSO suitable habitat definition described in table 2. Additional considerations are discussed in section 8.

Surface fuel: needles, leaves, grass, forbs, dead and down branches and boles, stumps, shrubs, and short trees.

Survey: a survey is the act or instance of inspecting a defined area for the presence of California spotted owl, according to whatever is the most current survey protocol at the time of surveying. The Strategy does not assume nor require use of any specific survey protocol, since protocols should evolve with new science and technology.

Territory (or core area): the area in a home range that is defended by the resident single or pair of owls from members of the same species.

Watershed Scale: the area within a contiguous watershed, typically a hydrologic unit code (HUC) 8 unit and more than 10,000 acres in size.

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Appendix 1. Safford and Stevens (2017) Excerpt

We finish by making the following general conclusions:

1. With regard to ecosystem composition of assessment-area YPMC forests, although overall plant species diversity across the assessment area has probably not changed much (except for the addition of nonnative species), there has been a major shift over the past century from dominance by shade-intolerant/fire-tolerant species to dominance by shade-tolerant/fire-intolerant species. This has happened in both the forest overstory and understory.
2. With regard to ecosystem structure, assessment-area YPMC forests are greatly changed from the presettlement period, so much so that people from the 18th or 19th centuries would probably not recognize the modern forest. For example:

    A. Mean adult tree densities are an average of two to four times higher today than during the presettlement period.

    B. Tree seedling densities are similarly much higher in the modern forest, and they are dominated by fire-intolerant/shade-tolerant species.

    C. The average tree in today's forest is 40 to 50 percent smaller (in d.b.h.) than in the presettlement forest.

    D. Even though there are fewer large trees in today's forest, the huge number of small trees has resulted in basal areas that are equal to or higher on average than in presettlement forests.

    E. Tree canopy cover averages about 33 percent more today than in the presettlement period.

If current trends in fire severity continue (Mallek et al. 2013, Miller and Safford 2012, Miller et al. 2009b), it seems likely that species of more mesic habitats will decrease in abundance and perhaps richness, while xeric species adapted to higher light and warmer conditions will expand (Stevens et al. 2015). Alien species richness is also likely to increase under this scenario.

Table 11—Summary of probable deviations from the natural range of variation (NRV) for yellow pine and mixed-conifer (YPMC) forests in the assessment area[a]

Ecosystem attribute	Indicator group	Indicator	Variable	Within NRV[b]	Confidence	See discussion on page:	Notes
Function	Disturbance	Fire	Fire regime	No	High	31	Shift from Fire Regime I to Fire Regimes III and IV.
Function	Disturbance	Fire	Fire frequency	No	High	34	Current frequency far below presettlement but rising.
Function	Disturbance	Fire	Fire severity	No	Medium to High	38	Current severity higher than presettlement and rising.
Function	Disturbance	Fire	Fire size	No	Medium	52	For fires >4 ha, current mean and mean maximum fire sizes larger than presettlement mean.
Function	Disturbance	Fire	High severity patch size	No	Medium	51	Current high-severity patch sizes higher than presettlement mean and rising.
Function	Disturbance	Fire	Fire rotation	No	High	37	Fire rotations much longer today than presettlement.
Function	Disturbance	Fire	Fire season	No	Medium	56	Fire season is becoming longer, but general seasonal patterns are similar.
Function	Disturbance	Fire	Annual area burned	No	High	55	Current mean annual area burned is much lower than all estimates of presettlement area (but it is rising quickly).
Function	Disturbance	Insect outbreaks	Tree mortality from insects	unknown		69, 84	Little in the way of presettlement estimates. Some conclusions can be drawn from comparisons of range of current conditions.
Structure	Physiognomy	Canopy cover	Percentage of cover	No	Medium	136	Modern mean canopy cover is above presettlement.
Structure	Physiognomy	Coarse woody debris (CWD)	Pieces of CWD per unit area	No	Medium	141	Density of CWD is higher in contemporary forests.
Structure	Physiognomy	Coarse woody debris	Mass of CWD per unit area	No	Medium	141	Average tons/ha of CWD is higher in contemporary forests.
Structure	Physiognomy	Forest fuels	Tons/ha	No	Medium	158	On average, contemporary YPMC forests support much higher fuel loadings than presettlement forests, in both fine-fuel and coarse-fuel classes.
Structure	Physiognomy	Functional groups/ growth forms	Proportion of early/ middle/late seral forest	No	Medium	87	Current lack of old-forest successional stages, perhaps some localized lack of early stages.
Structure	Physiognomy	Gap size distribution	Gap size	No	Medium	139	Gap sizes are generally decreasing (in undisturbed forests), but also increasing in disturbed forests owing to more severe disturbance.

Table 11—Summary of probable deviations from the natural range of variation (NRV) for yellow pine and mixed-conifer (YPMC) forests in the assessment area[a] (continued)

Ecosystem attribute	Indicator group	Indicator	Variable	Within NRV[b]	Confidence	See discussion on page:	Notes
Structure	Physiognomy	Grass and forb cover	Percentage of cover	Maybe	Low	153	Difficult to assess, little presettlement data. Overall herbaceous cover on landscape may be similar; cover within forest stands may be lower owing to fire suppression.
Structure	Physiognomy	Overstory density	Number of trees per unit area	No	High	97	Current density higher on average than presettlement.
Structure	Physiognomy	Overstory density	Number of large trees per unit area	No	High	97	Large tree density is lower in modern forests.
Structure	Physiognomy	Shrub cover	Percentage of cover	Maybe	Low	148	Difficult to assess, little presettlement data. Overall shrub cover on landscape not much changed over time; cover within forest stands may be lower owing to fire suppression.
Structure	Physiognomy	Snag density	Number of snags per unit area	No	Medium	141	Snag density is higher in contemporary forests.
Structure	Physiognomy	Tree size class distribution	Tree size-class distribution	No	High	99	Major increases in small size classes, and general decreases in large size classes. Change in distribution shape from ± flat, hump-shaped, or weakly J-shaped in average presettlement forest to strongly J-shaped in average modern forest.
Structure	Physiognomy	Average tree size	Mean d.b.h. or quadratic mean diameter	No	High	99	Average conifer tree in modern YPMC forests about one-half the diameter of the average tree in presettlement forests.
Structure	Productivity	Tree basal area	Basal area	Yes	Medium	107	Basal area similar if a bit higher in modern forests; major difference is distribution of more biomass in small and medium trees in contemporary forest than in presettlement forest.
Composition	Functional diversity	Functional groups/ growth forms	Proportion of shade tolerant vs. shade intolerant species	No	High	160	Major shift from dominance of shade-intolerant species to dominance of shade-tolerant species.
Composition	Species diversity	Species richness	Plant species richness	Yes	Medium	161	No evidence of major species loss.

d.b.h. = diameter at breast height. TBD = to be determined.

[a] NRV presettlement reference period is assumed to refer to 1500/1600 to 1850, unless otherwise indicated in notes. NRV for most indicators/variables also includes information from contemporary reference sites.

[b] As defined as the range of means from multiple sources.

F. Forest structure has been greatly homogenized, with the size and number of forest gaps decreasing almost to zero in many modern forest stands. In presettlement forests, many areas supported more canopy gaps than canopy.

G. Contrary to what many people think, an objective assessment of the evidence suggests that snag densities and coarse woody debris are not depleted in modern forests, and indeed most of the evidence suggests they are **more** abundant today than in the average presettlement forest stand.

H. Coarse woody debris is also a component of forest fuels, and modern fuel loadings are much higher today than in the presettlement forest. Our estimate is that fuel loadings in assessment-area YPMC forests have risen by an average of 70 to 100 percent over the past century or so.

I. Shrub cover in modern YPMC forests is probably not very different from presettlement conditions (maybe slightly lower today), but the distribution of shrub cover certainly is. Modern forests are more likely to support large areas of contiguous shrub fields but relatively low shrub cover within forest stands (owing to higher stand canopy cover today), whereas presettlement forests supported higher cover of shrubs within stands, as light incidence at the soil surface was much higher.

3. With regard to ecosystem function, the major change in YPMC forests has been in the role and behavior of fire. Specifically:

A. Fires have gone from representing a frequently recurring disturbance on the landscape (5 to 10 events per century on average) to an extremely rare event (75 percent of all YPMC forest has not seen a fire in the past 100+ years).

B. The average area of fire in the assessment area between 1984 and 2010 was only about 10 to 15 percent of the presettlement mean (±150 000 ha per year), but the past 6 years have seen much more area burn, with large areas experiencing nearly complete tree mortality.

C. When fire occurs today, it behaves very differently on average than in the presettlement forest because of differences in forest structure and fuels, and as a result of changing climate. The proportional area of fires burning at high severity today (severity is a measure of mortality caused by fire or biomass lost to fire) is 5 to 10 times greater than in the average presettlement period fire.

4. As such, the role of fire has changed from one of forest maintenance (of relatively open-canopy, low-fuel-accumulation conditions with dominance primarily by fire-tolerant species) to one of forest transformation, where dense stands of fire-intolerant species and heavy fuel accumulations are more likely to burn at high severity, resulting in major ecosystem changes.

For decades, the major ecological issue in the assessment area was thought to be the loss of dense-canopied, old-growth forest to logging, and threats to wildlife species that depend on such conditions (Duane 1999, Ruth 1996). Today the major threat is clearly the loss of forest—old growth or not—to severe wildfire and insect and direct drought mortality (Keeley and Safford 2016, McKenzie et al. 2004). The irony is that a primary cause of this major threat is the historical widespread focus on fire suppression, which was viewed as a necessary means to prevent forest loss. In light of new scientific information, such as the information presented in this report, these management views have been changing, and we are at a pivotal point in resource management in the assessment area. Current trends in climate, fire, human land use, economics, and federal budgets are not auspicious, but recent collaborative management efforts at large landscape scales, political developments in California, and more progressive national forest planning suggest that there is a broadening understanding of the necessary ecological role of fire in the Sierra Nevada bioregion. We hope that this assessment of past and current conditions in the broader Sierra Nevada bioregion will add to this growing understanding and support effective management that can conserve California's "Range of Light."

Today the major threat is clearly the loss of forest—old growth or not—to severe wildfire and insect and direct drought mortality (Keeley and Safford 2016, McKenzie et al. 2004). The irony is that a primary cause of this major threat is the historical widespread focus on fire suppression, which was viewed as a necessary means to prevent forest loss.